

## RF MATCHING CIRCUIT FOR CANREB RFQ\*

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### Abstract

A RF matching circuit has been developed to provide two phase RF voltage of 1.2 kVpp at 3 MHz and 6 MHz for the CANREB RFQ structure with an equivalent capacitive load of 300 pF. The RF matching circuit utilizes pi-network with two phase transformer. Beyond RF drive the CANREB structure requires pulse DC bias with amplitude up to 500 V. Results of development and testing of RF matching circuit and filters are presented in this paper.

### INTRODUCTION

The matching circuit is used to match the amplifier and the RFQ structure. The RF matching circuit provides 1.2 kVpp RF voltage through two coaxial cables by means of vacuum feedthrough for an equivalent load capacitance of 200 pF (RFQ electrode capacitance of approximately 170 pF & 130 pF parasitic capacitance from cable). There are two operating frequencies at 3 MHz and 6 MHz and we employ dedicated matching circuit for each frequency. Separate DC filters will be used to prevent leakage of RF to DC sources [1].

### RF CIRCUIT DESIGN

The circuit comprised of both off-the-shelf fixed value RF capacitors and RF variable air-gap capacitors, along with two hand-wound inductors (primary/secondary) as shown in Fig. 1. Since only one frequency will be in operation at a given time, two separate RF box was design and developed [2].

The primary side of the circuit consist of two variable capacitors (C2 & C3) and primary winding (L1 & L4) in a pi-network configuration, used for matching the RF source impedance of 50 ohms with a higher impedance circuit. The secondary side of the circuit consist of a secondary winding (L2 & L3), centre tapped. The primary and secondary winding are weakly coupled with an assumed coupling factor (k) of 0.045. Two additional capacitors (C4 & C5) are used for resonance frequency adjustment.

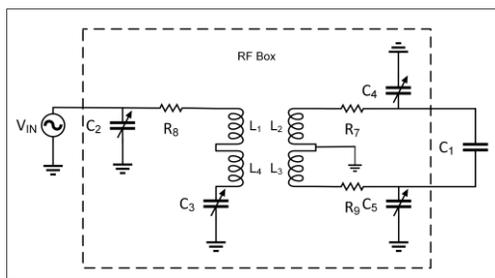


Figure 1: Schematic of RF Circuit.

### SIMULATIONS

The circuit was simulated in SPICE with the values as in Table 1 and input file shown in Table 2. It is estimated that an input power of 11 W is required for an output voltage of 600 V amplitude, as shown in Fig. 2.

Table 1: Component Simulation Values

	Values		Values
C1	0.2 nF	C3	2.25 nF
C4 / C5	0.4 nF	R7 / R9	0.2 Ω
C2	2.81 nF	R8	0.3 Ω
L1 / L4	1.4 μH	k1 / k2	0.045
L2/ L3	3.5 μH		

Table 2: SPICE File for Simulation

```

CANREB_3MHz.cir
* signal source and function generator
v.in 1 0 ac 33 sin(0 33 3MEG 0 0 0 )
r50 1 0 50 ;*50ohm source
* RF circuit
r8 1 2 0.3 ;* R8
c2 1 0 2.81n ;* C2
l1 2 3 1.4u ;* L1
l4 3 7 1.4u ;* L4
l2 4 0 3.5u ;* L2
l3 0 8 3.5u ;* L3
k1 11 12 45m ;*coupling factor
k2 14 13 45m ;*coupling factor
c3 7 0 2.254n ;*C3
r7 4 6 0.2 ;*R7
r9 8 5 0.2 ;*R9
c1 6 5 0.2n ;*C1
c4 6 0 0.39n ;*C4
c5 5 0 0.39n ;*C5
* Voltage pickup
c.m1 5 9 20p ;*Measurement cap
r.m1 9 0 50 ;*50ohm
c.m2 6 10 20p ;*Measurement cap
r.m2 10 0 50 ;*50ohm
* analysis commands
.ac dec 10000 1meg 6meg
.probe
.end
    
```

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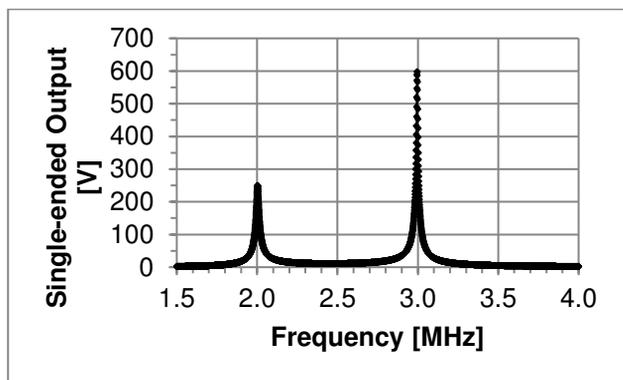


Figure 2: Output of matching circuit: 2 MHz push-push and 3 MHz push-pull modes.

### RF BOX DESIGN

The RF circuit was manufactured in a box designed with a removable shelf for ease of interchanging between 3 MHz and 6 MHz. The inputs, outputs, and adjustment knobs of the box were all placed on the front panel, with two forced air-cooling fans for the primary and secondary coil as shown in Fig. 3. RF circuit was manufactured in a box designed with a removable shelf for ease of interchanging between 3 MHz and 6 MHz.

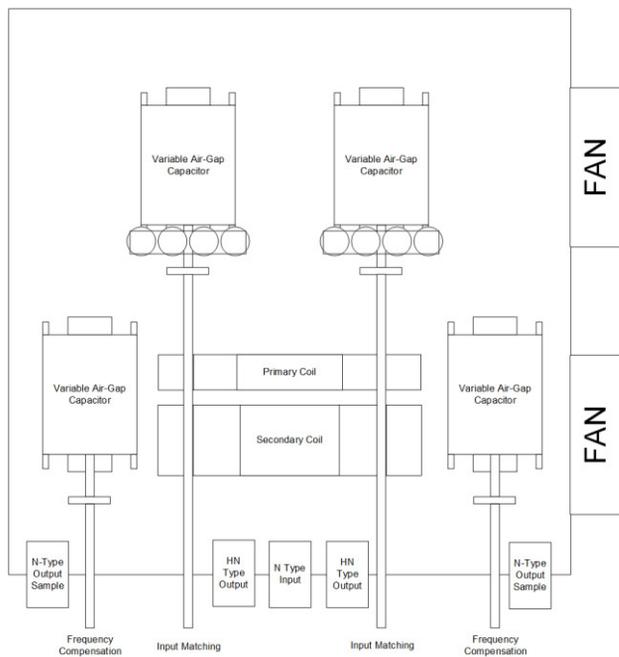


Figure 3: RF Box design.

### BENCH TEST RESULTS

Prior to connecting the RF box with the amplifier, low level measurements can be performed using a network analyzer. The matching can be measured using the reflection coefficient (S22) on the network analyzer by connecting to the input of the RF box, as shown on Fig. 4. Once a good matching and correct resonance frequency are achieved by adjusting C2- C5, the RF box can be tested at full power.

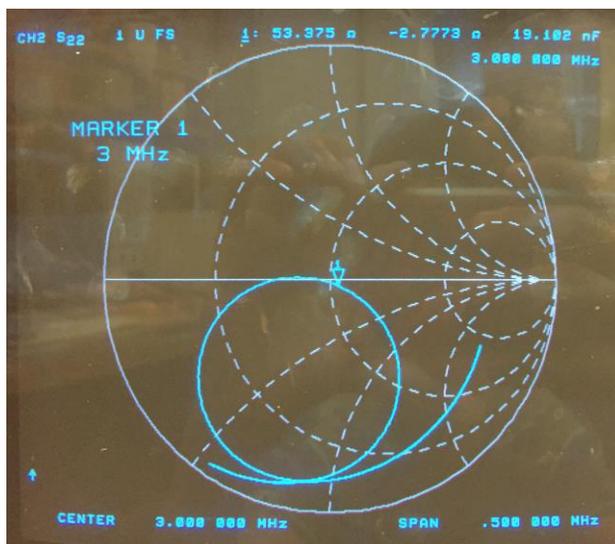


Figure 4: Measurement of matching with S11.

In order to drive the RF box (Fig. 5), a signal generator and amplifier was used. The forward power was monitored with an analog power meter. The matching of the circuit was monitored with a bi-directional coupler. The output of the RF box was connected to a capacitive load 200 pF capacitor with two high voltage probes (P5100A) what had a parasitic load capacitance of approximately 2.5 pF. The setup is shown in Fig. 6. The 3 MHz RF box was tested in the lab, achieving an output voltage of 1.2 kVpp with 22 W input power. After the design was tested, two additional capacitor dividers were added for voltage pickup. The 6 MHz RF box has also been prototyped and tested.

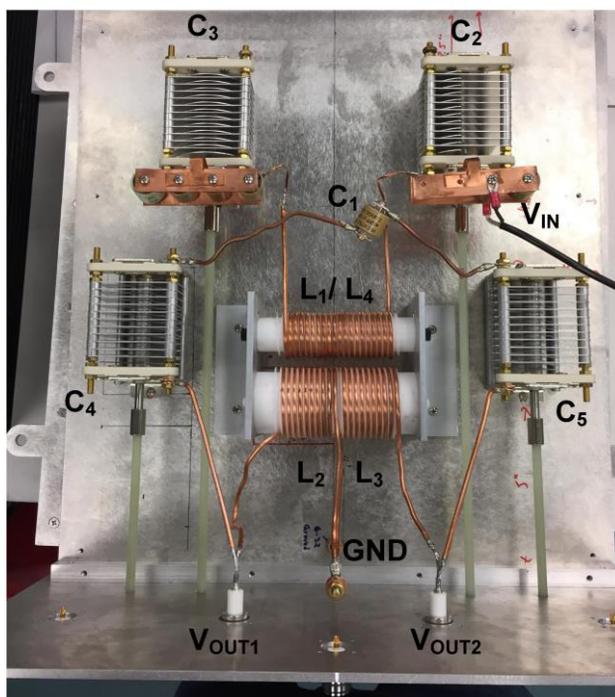


Figure 5: Manufactured RF Box.

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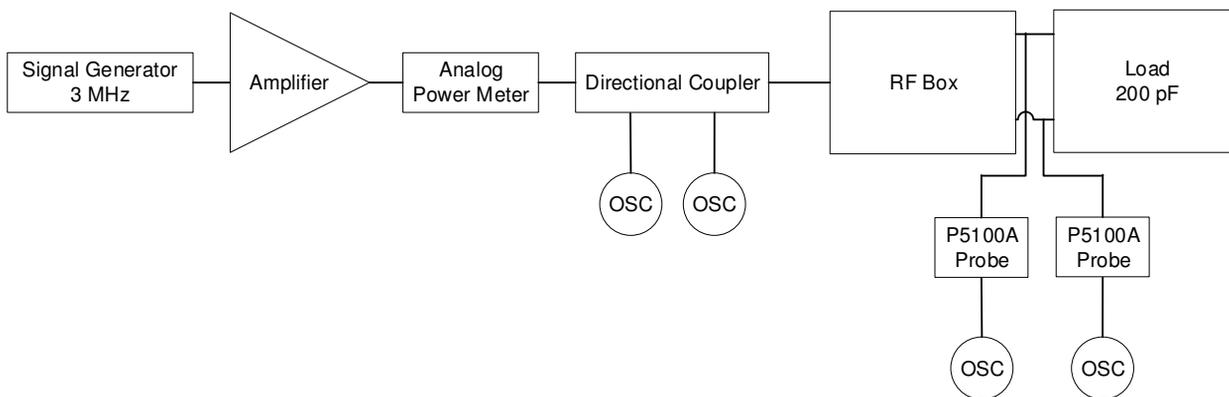


Figure 6: Block diagram of test setup for RF Box.

### DC NOTCH FILTER DESIGN

In order to prevent the RF signal from damaging the power supplies, RF filters are required. Due to the requirement of short rise-time and fall times for switching the RFQ segments, a notch filter has been designed and prototyped as shown in Fig. 7, rather than a simple low pass filter. Approximate values of inductance and capacitance were used for the prototype because the filter is highly dependent on the cable length and output resistance of the power supplies. The final values can only be determined once the CANREB RFQ and cables are installed in the final position. Initial results demonstrate 20 dB attenuation at 3 MHz (Fig. 8).

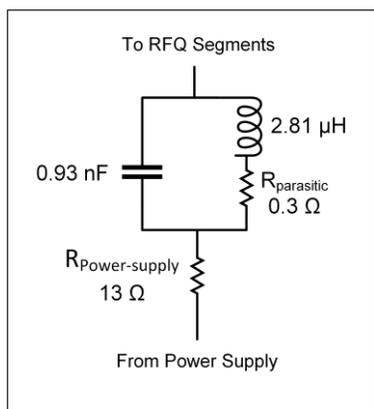


Figure 7: DC notch filter.

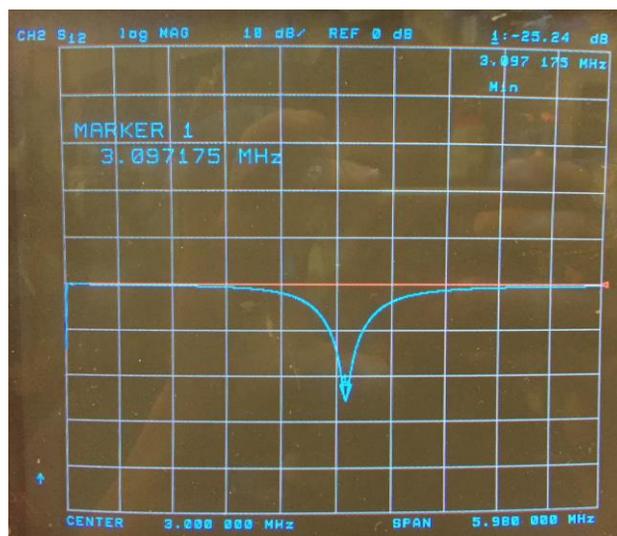


Figure 8: Frequency response for DC filter.

### CONCLUSION

The 3 MHz RF box has been tested with the CANREB RFQ buncher off-line and the design of the DC filter box have been prototyped, scheduled to be tested with other sub-systems later this year. The final 6 MHz RF box will be available in late 2018.

### ACKNOWLEDGMENTS

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### REFERENCES

- [1] B. Barquest, "Work Package and Requirement for CANREB RFQ RF Circuit," TRIUMF, Vancouver, Canada, Document: 126964, Jan. 2016.
- [2] V. Zvyagintsev and T. Au, "Design Review for the RF Circuitry of the CANREB RFQ Buncher," TRIUMF, Vancouver, Canada, Document: 138683, Dec. 2016.