One

Versatile Bandpass Filters with Wide Frequency Tunability Part III

Version 1.0

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Synopsis

This is part 3 and the final installment of my write-up concerning tunable LC bandpass filters. Circuit board details along with measurements are provided herein.

1 Introduction

This is part 3 and the final installment of my paper about tunable LC-based bandpass filters. Detailed schematics of the prototype filter board along with measurement results are provided herein.

2 Summary of Results

- Measurement results came in largely as anticipated.
- Inductor-Q led to fairly high insertion loss for the lowest frequency band tunable filter (10 – 20 MHz), but quite useable for the frequency synthesis application this is intended for.
- Tuning range was marginal at the top-end of the 80 – 160 MHz bandpass filter primarily because I purposely tried not to use the very low voltage portion of the varactor C-versus-V curves for improved linearity, even though the adopted varactors do not have much excess capacitance ratio (i.e., C(9V) / C(1V)).
- If the varactor choices remain unchanged (primarily for cost and availability reasons), the filter break-points should probably be rearranged to cover something more like 0.8 octaves rather than a full octave of frequency so that frequency coverage is less strained.
- Stopband performance out to 1.2 GHz and beyond was quite good, even for the lowest frequency bandpass filters. This validates the construction / grounding philosophy quite well and largely dispels the need for isolation walls or partitions on the board. Note, the circuit board is only two layers.
- The touch-LCD plus Arduino proved to be a very convenient means to easily provide varactor tune voltages to the filters.
- Two-capacitor adjustability at the filter input and outputs provide an attractive amount of flexibility in modifying the filter’s bandwidth and flatness characteristics as a function of center frequency.
- If lower insertion loss is desired, inductor-Q’s and percentage bandwidths would need to be revisited.

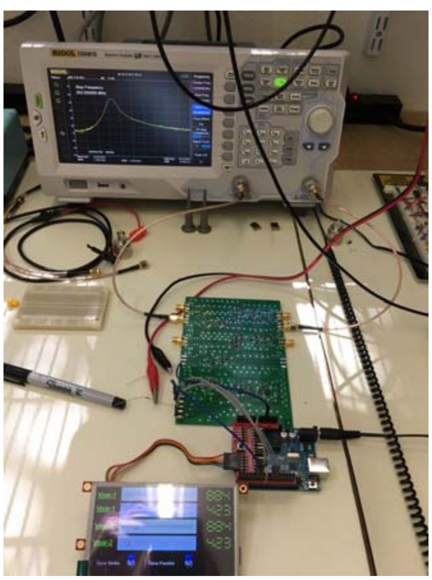


Figure 1 Tunable prototype filter board, Arduino Uno, and LCD display with adjustable varactor voltages

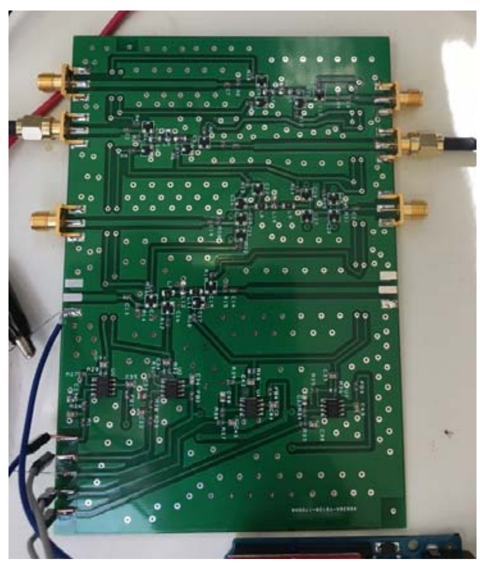


Figure 2 Close-up of prototype board. 3 of 4 filters with SMA connectors visible. Op-amp tune voltage amplifiers at the bottom for 2 independent series-tune voltages, and 2 independent parallel-tune voltages.

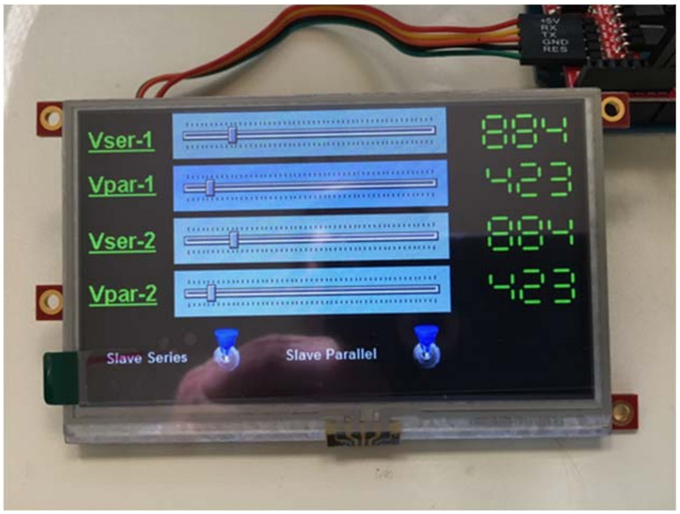


Figure 3 Close-up of LCD display. Arduino's PWM output voltages shown numerically. The LCD is by 4D Systems.

3 Measurement Results

Rough measurement results for 3 of the 4 prototype filters are summarized in Table 1. Accompanying graphical results are provided in the figures following.

Table 1 Filter Measurement Results

Filter	Frequency	V_{ser} [1]	V_{par}	Figure	Insertion Loss, dB	Comments
40 – 80 MHz	40	630	385	Figure 8	5	
	60	921	752	Figure 9	5	
	80	1908	1382	Figure 10 Figure 11 Figure 12	5	 Wide view Very wide view
80 – 160 MHz	80	771	188	Figure 13	5	
	120	1438	630	Figure 14	5	
	154	2115	865	Figure 15 Figure 16	3	
10 – 20 MHz	10	404	517	Figure 4	7	
	15	686	1072	Figure 5	7	
	20	1090	2153	Figure 6 Figure 7	2	 Wide view

[1] As displayed on LCD in mV. Voltage multiplication factor to actual varactor tune voltages is about 4.16.

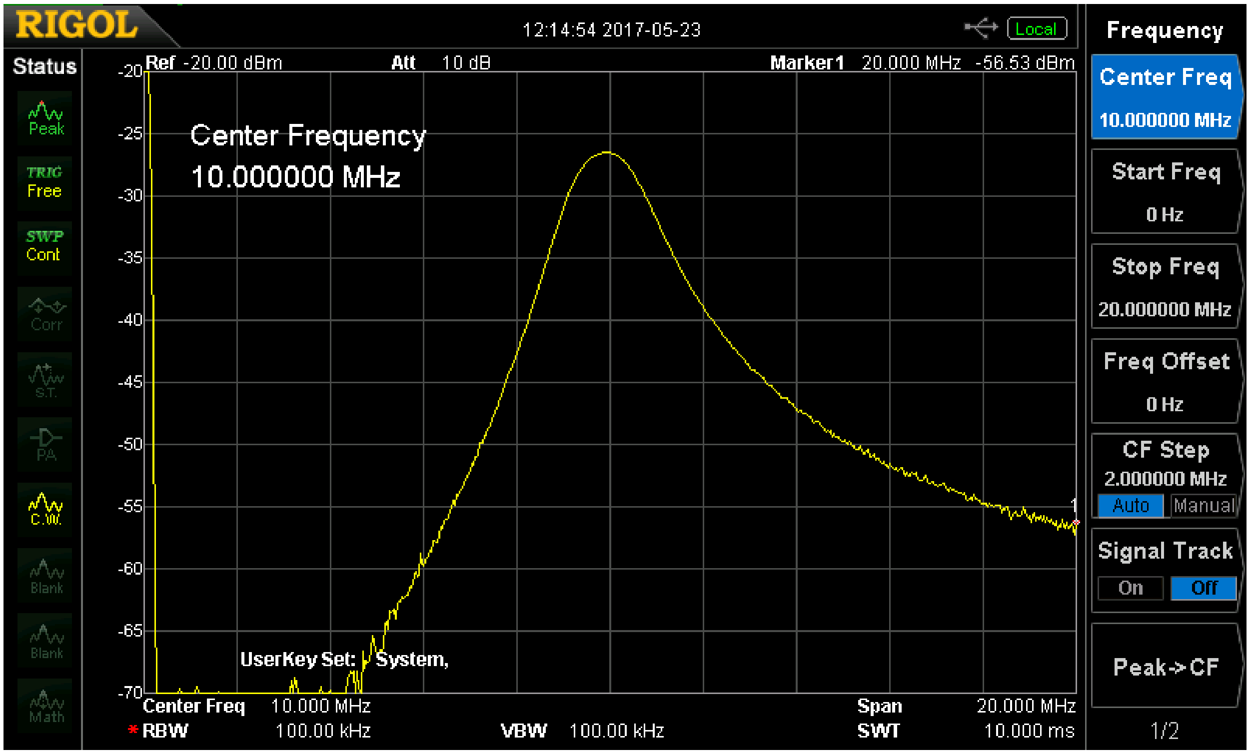


Figure 4 10 – 20 MHz. 10 MHz center frequency.

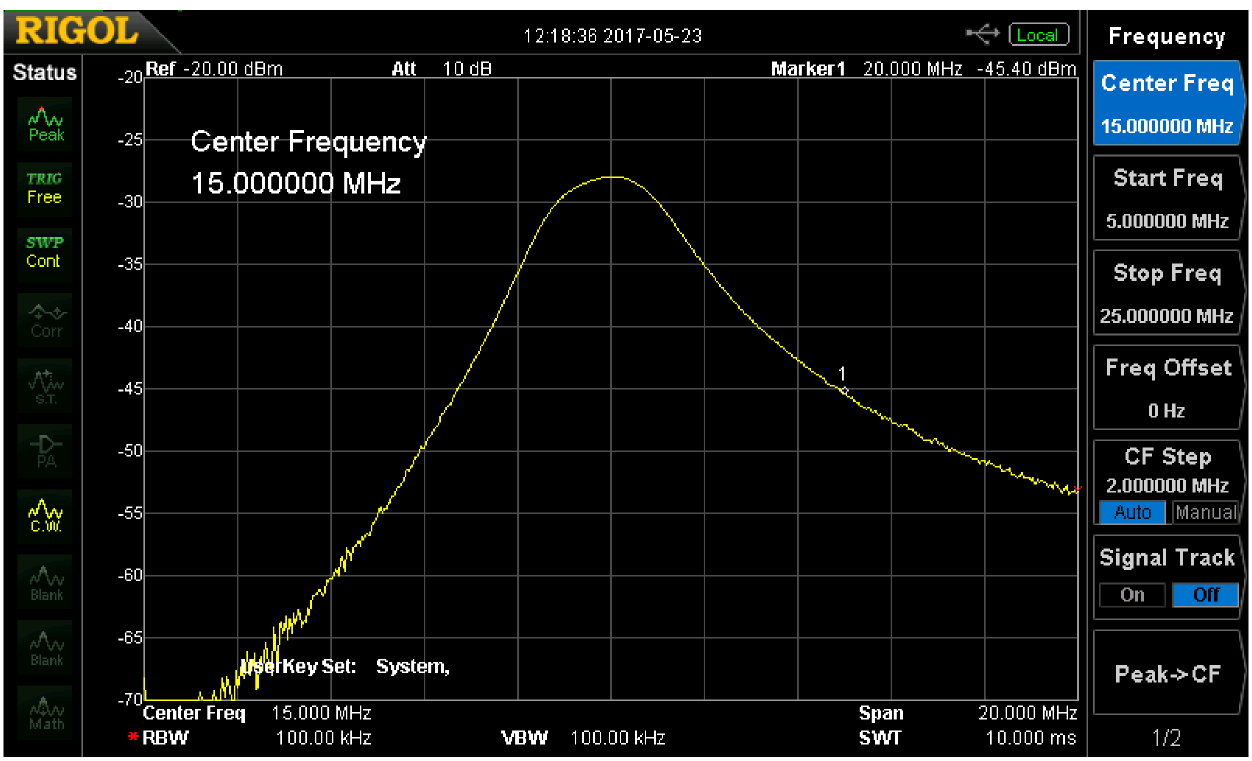


Figure 5 10 – 20 MHz. 15 MHz center frequency.

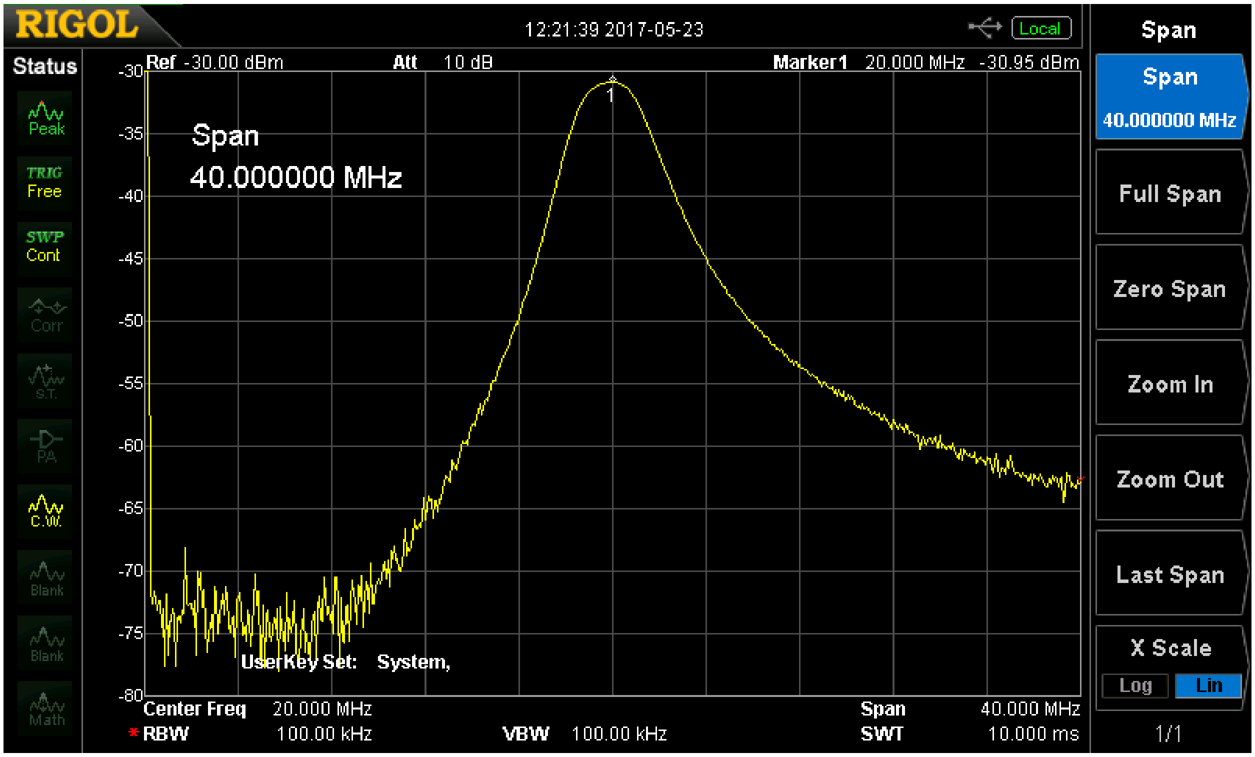


Figure 6 10 – 20 MHz. 20 MHz center frequency.

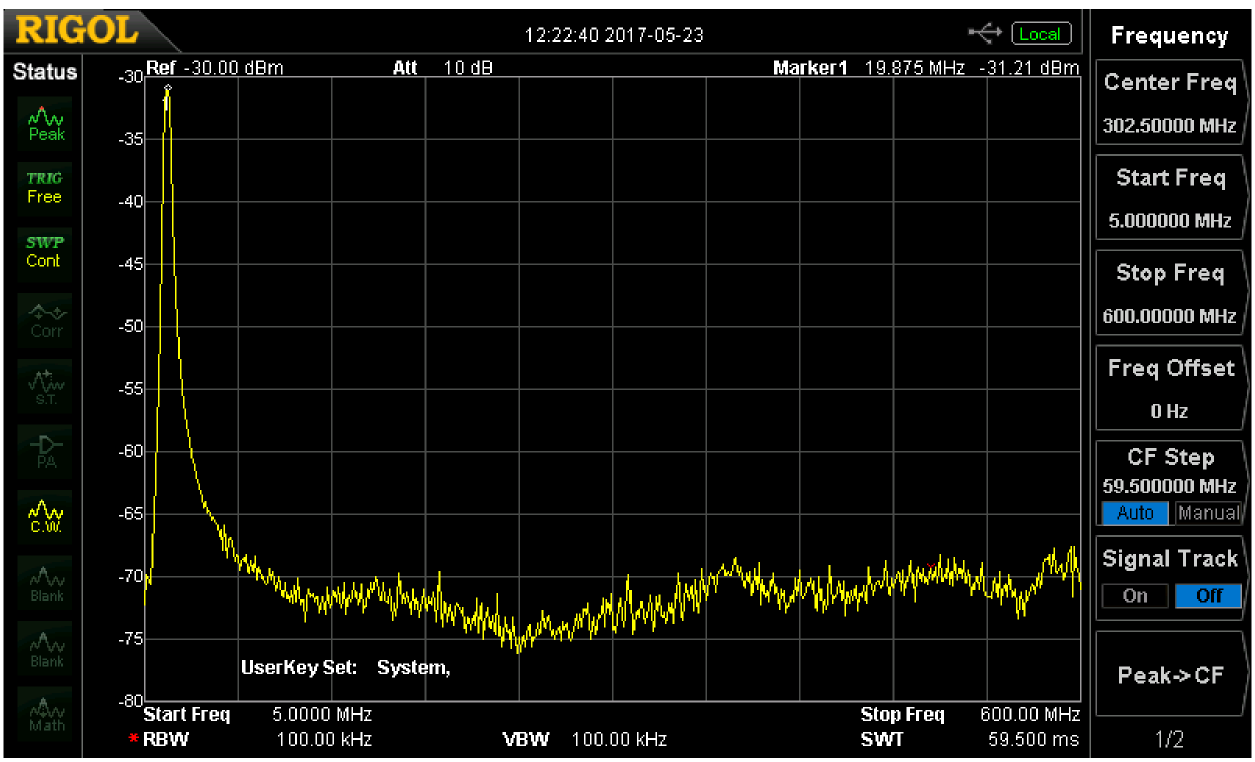


Figure 7 Wide view of Figure 6

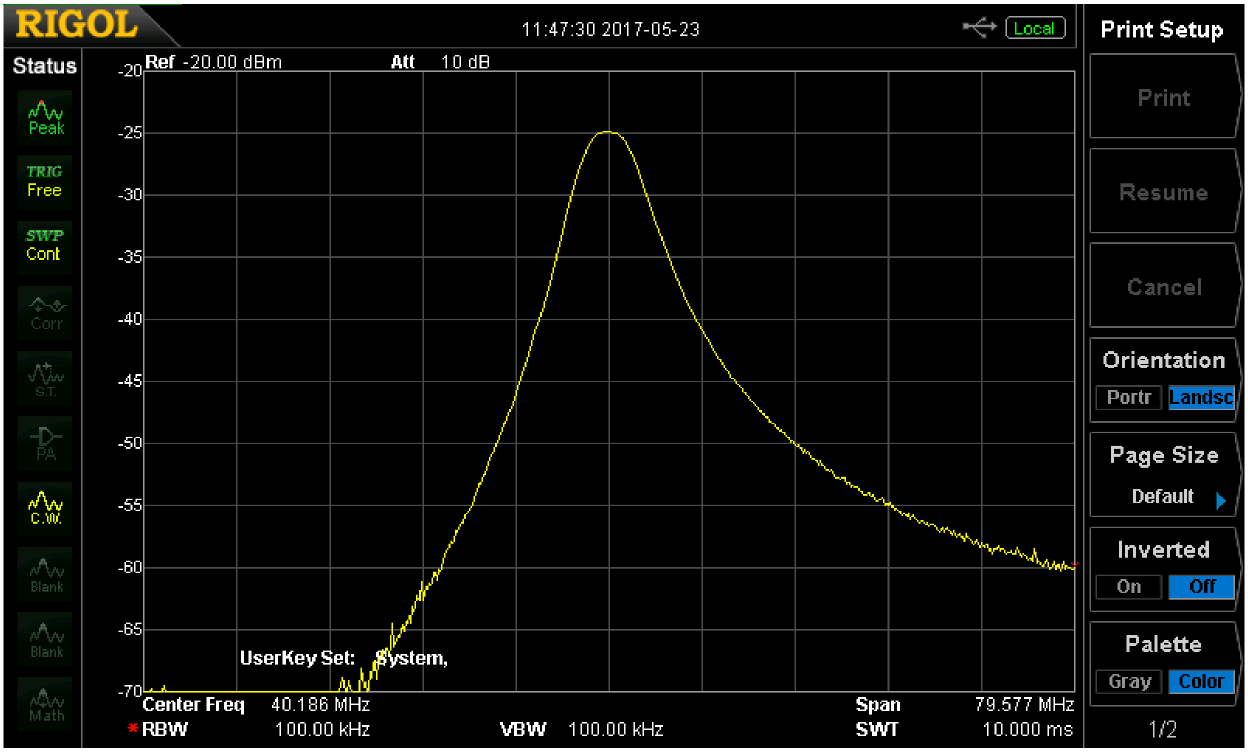


Figure 8 40–80 MHz Filter. 40 MHz center frequency.

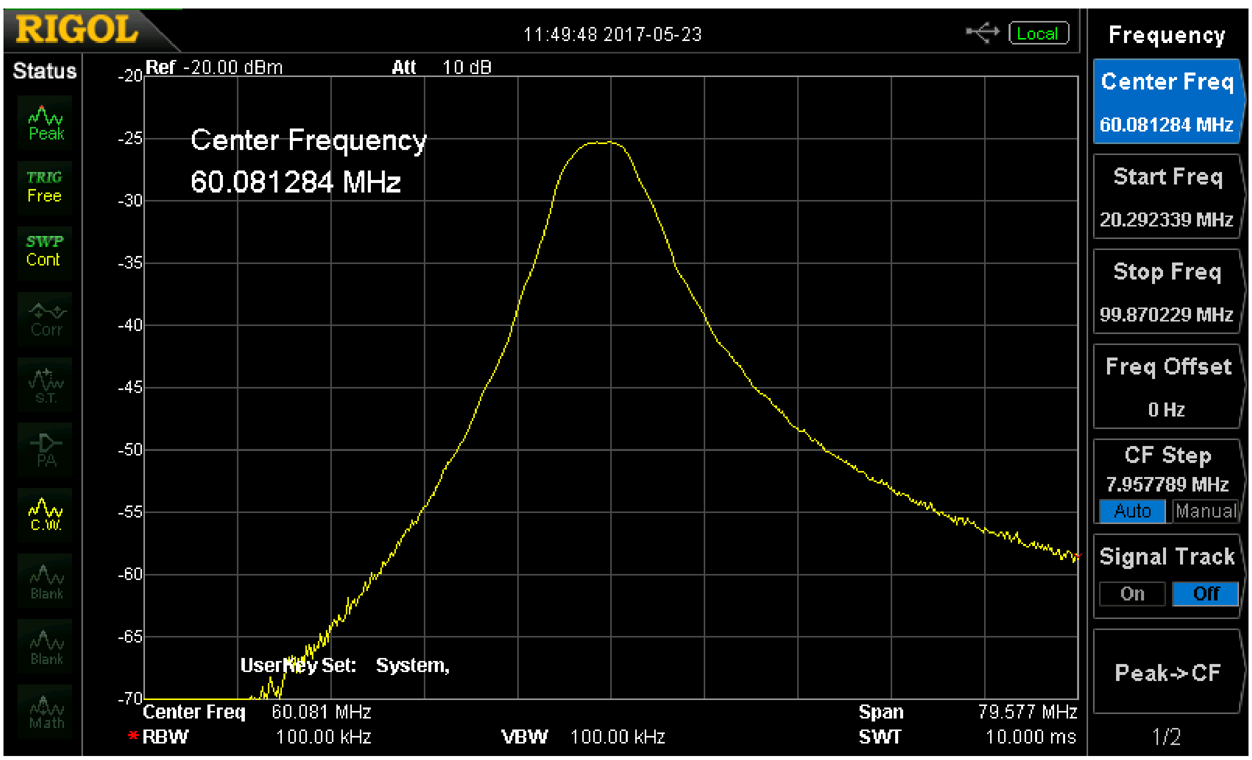


Figure 9 40–80 MHz Filter. 60 MHz center frequency.

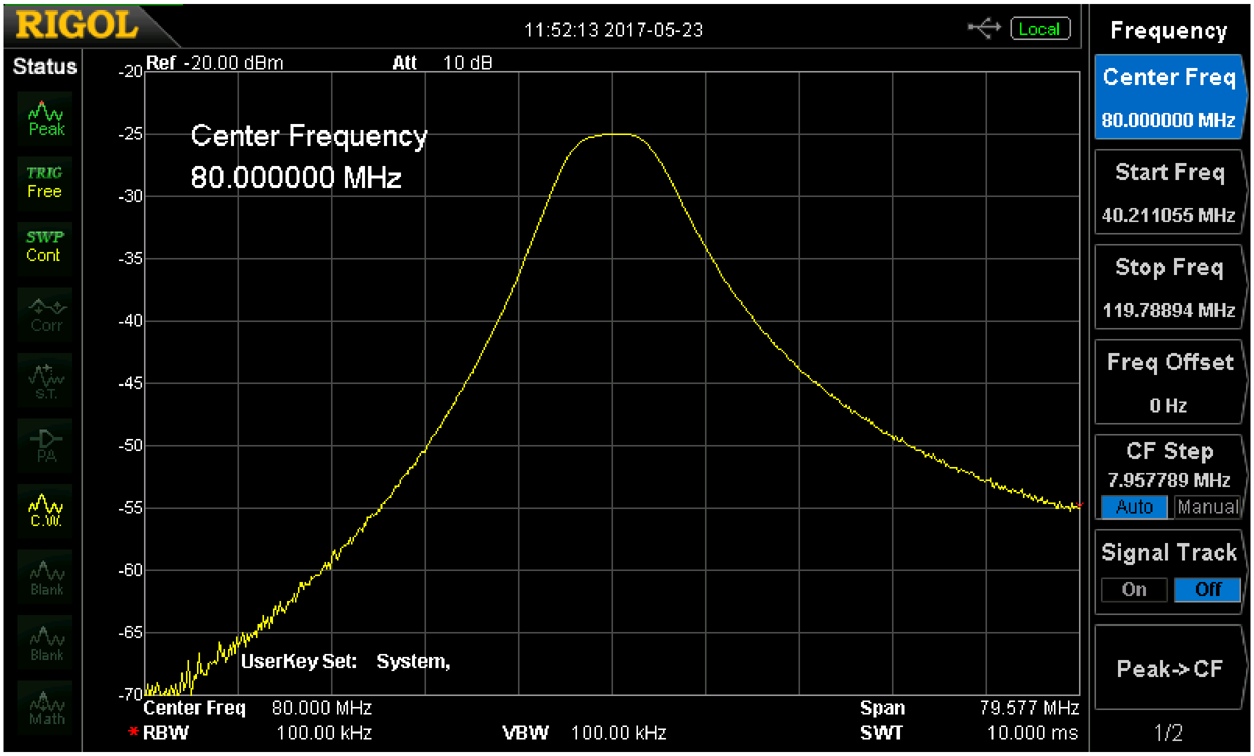


Figure 10 40–80 MHz Filter. 80 MHz center frequency.

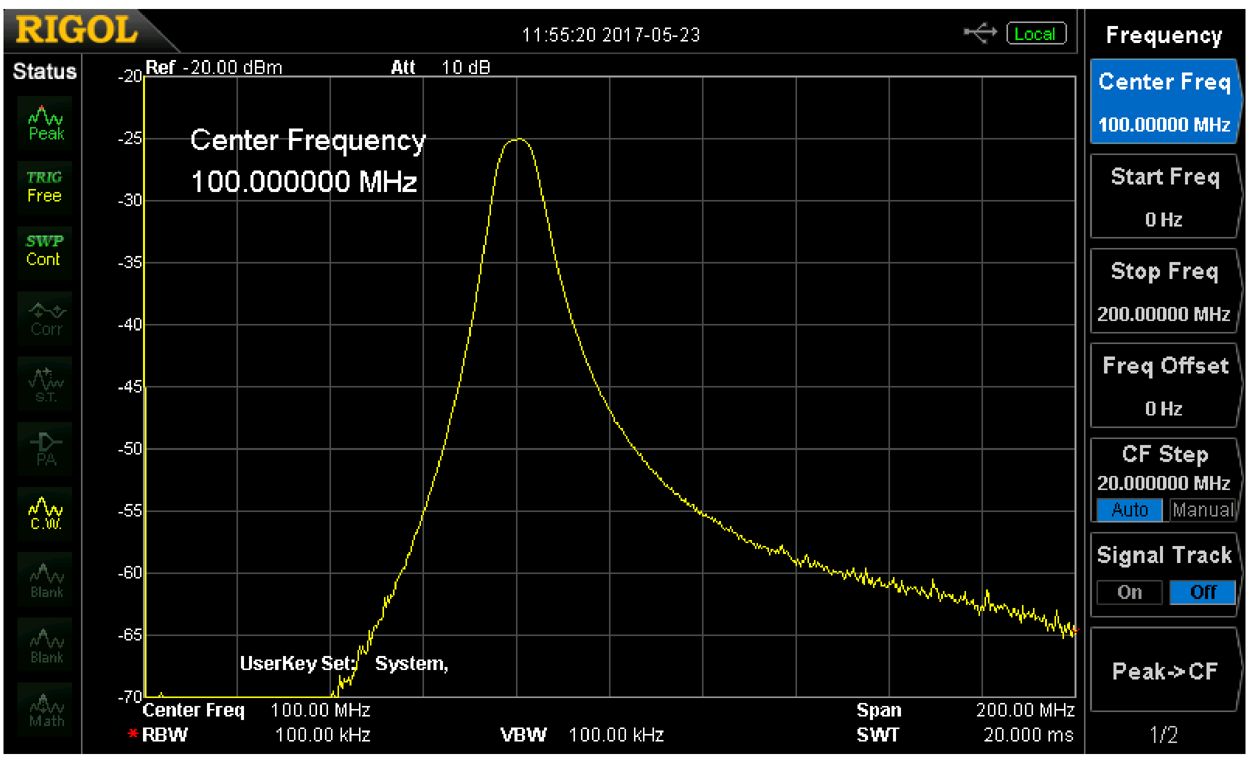


Figure 11 Wide frequency view of Figure 10

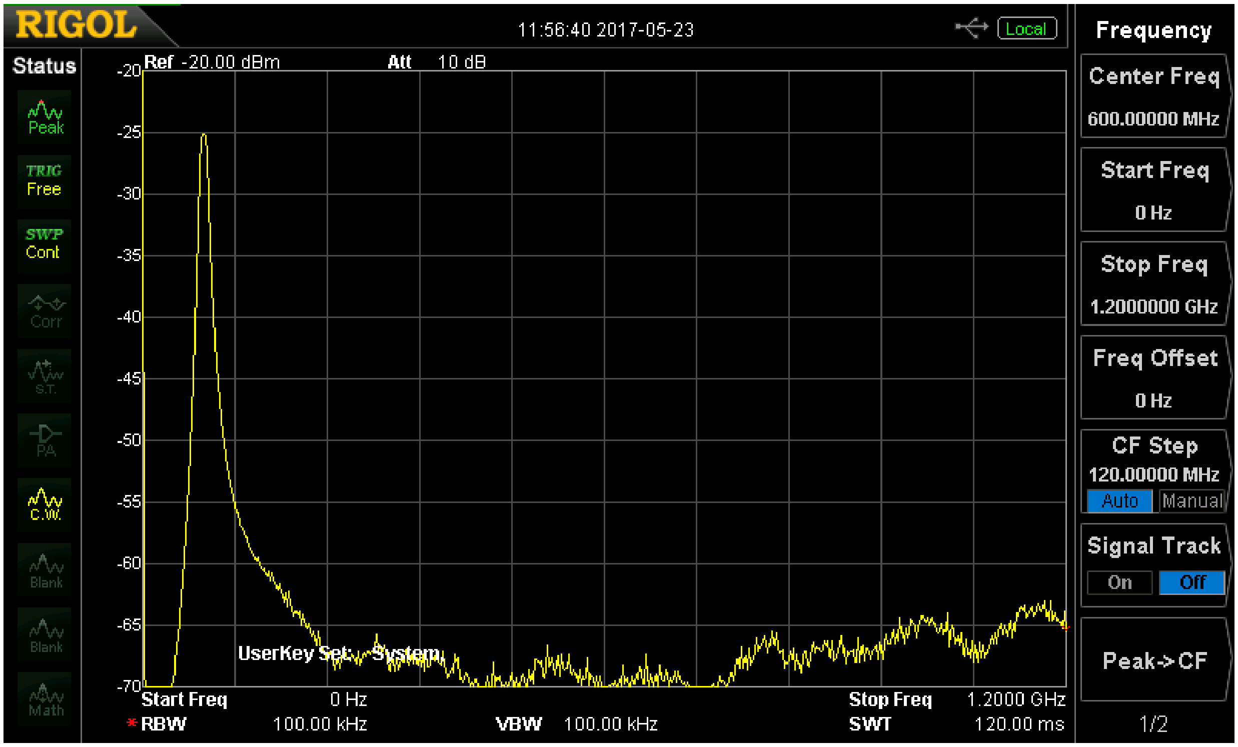


Figure 12 Very wide frequency view of Figure 10

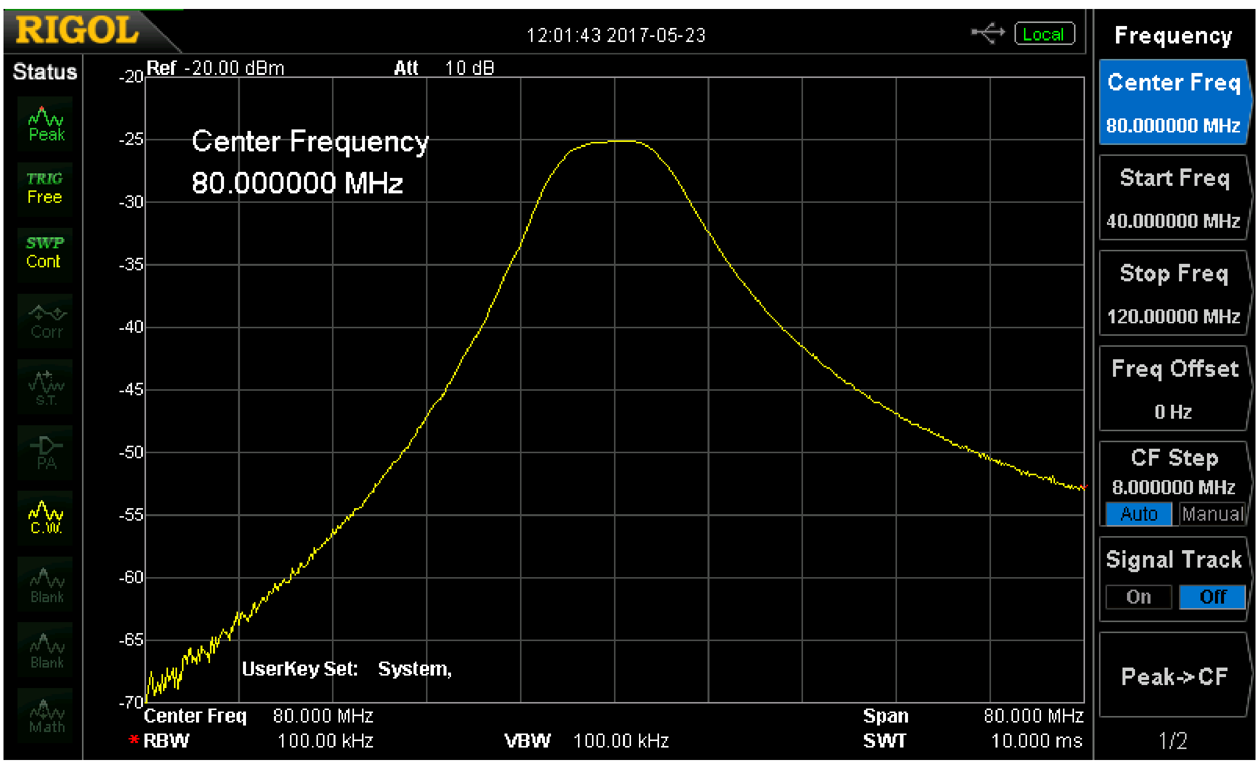


Figure 13 80–160 MHz Filter. 80 MHz center frequency.

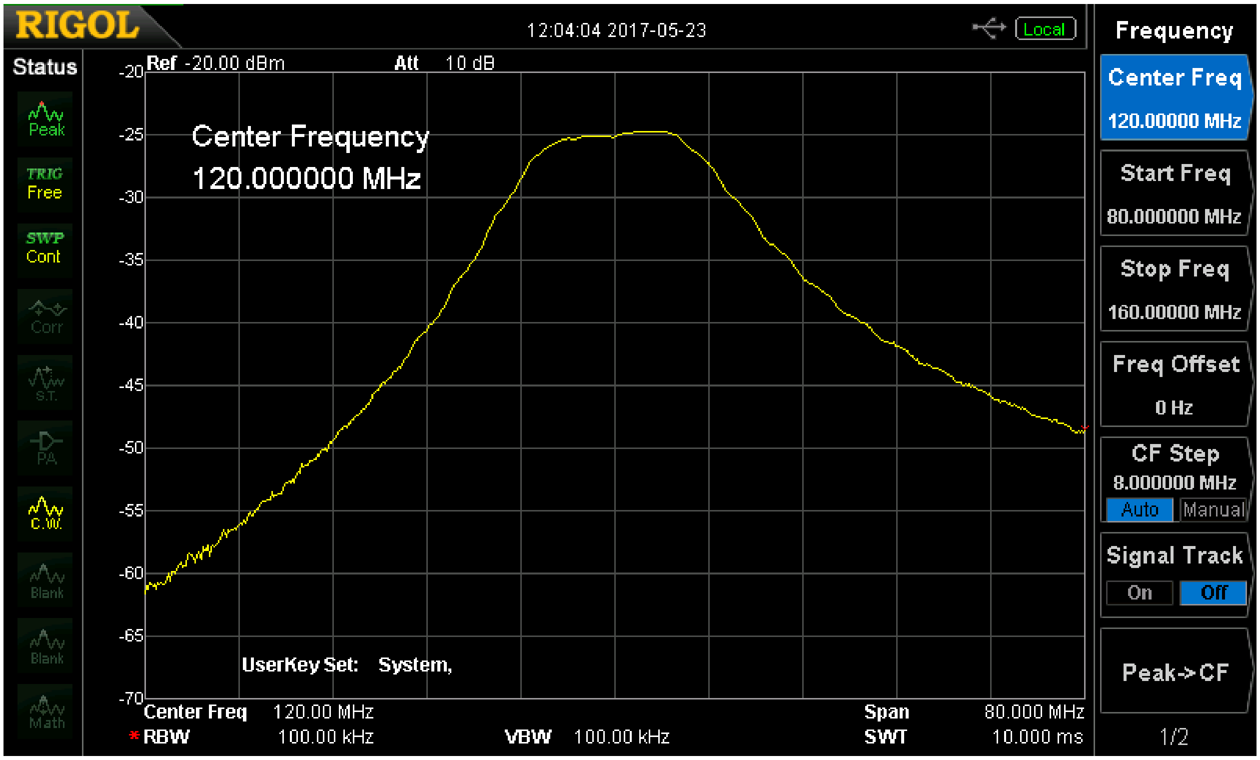


Figure 14 80–160 MHz Filter. 120 MHz center frequency. Slight waviness in the trace is due to a small amount of residual ripple on one of the varactor tune voltages.

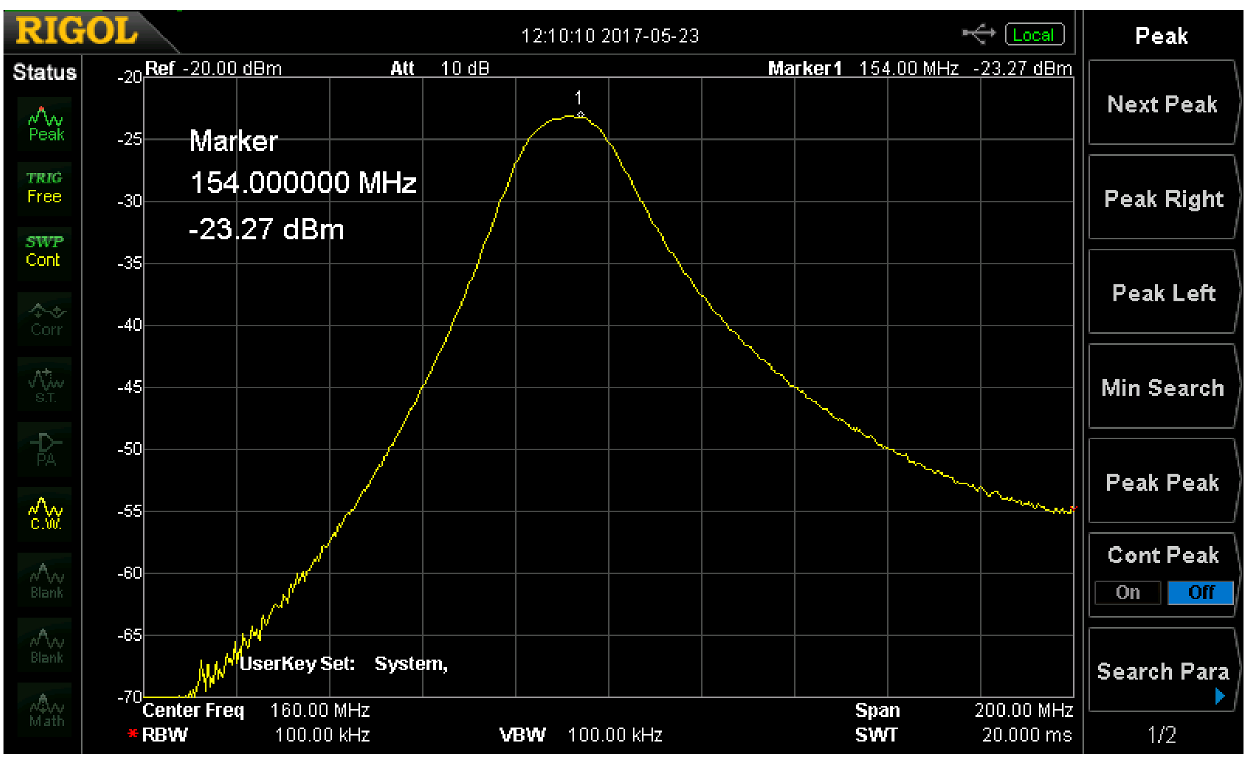


Figure 15 80–160 MHz Filter. 154 MHz center frequency. Unable to reach 160 MHz even with less than ideal passband.

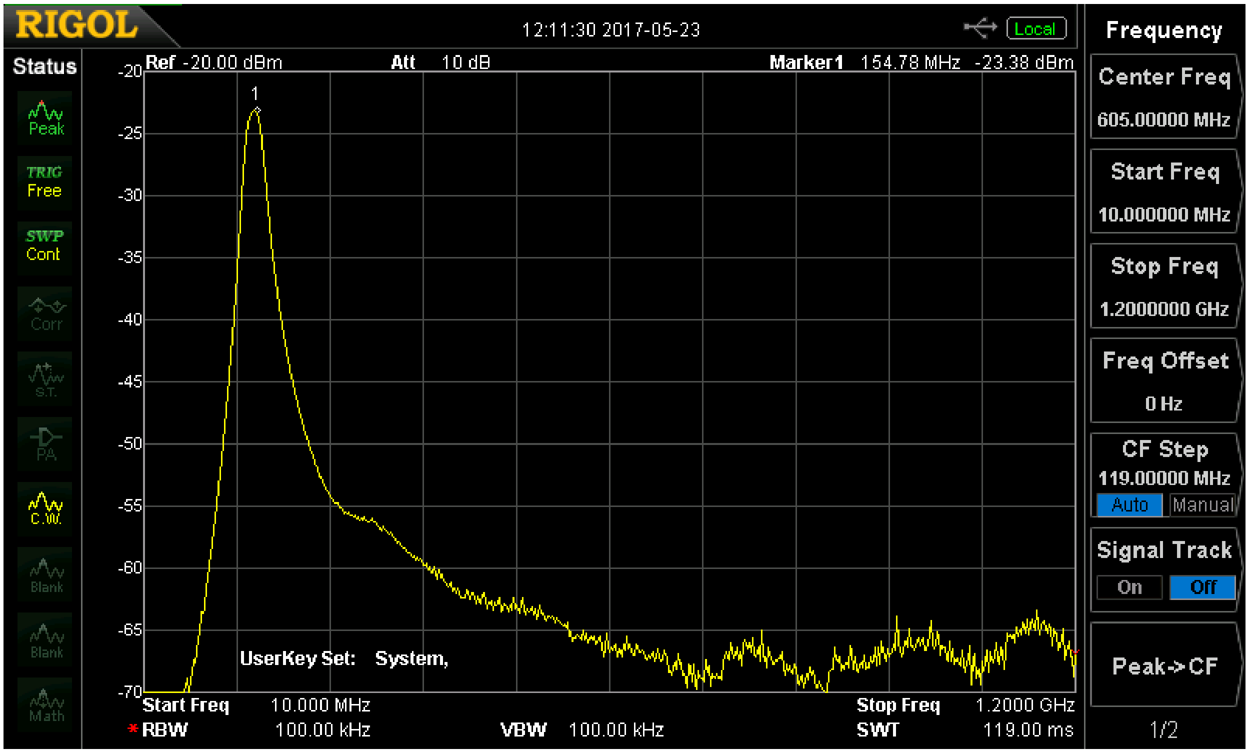
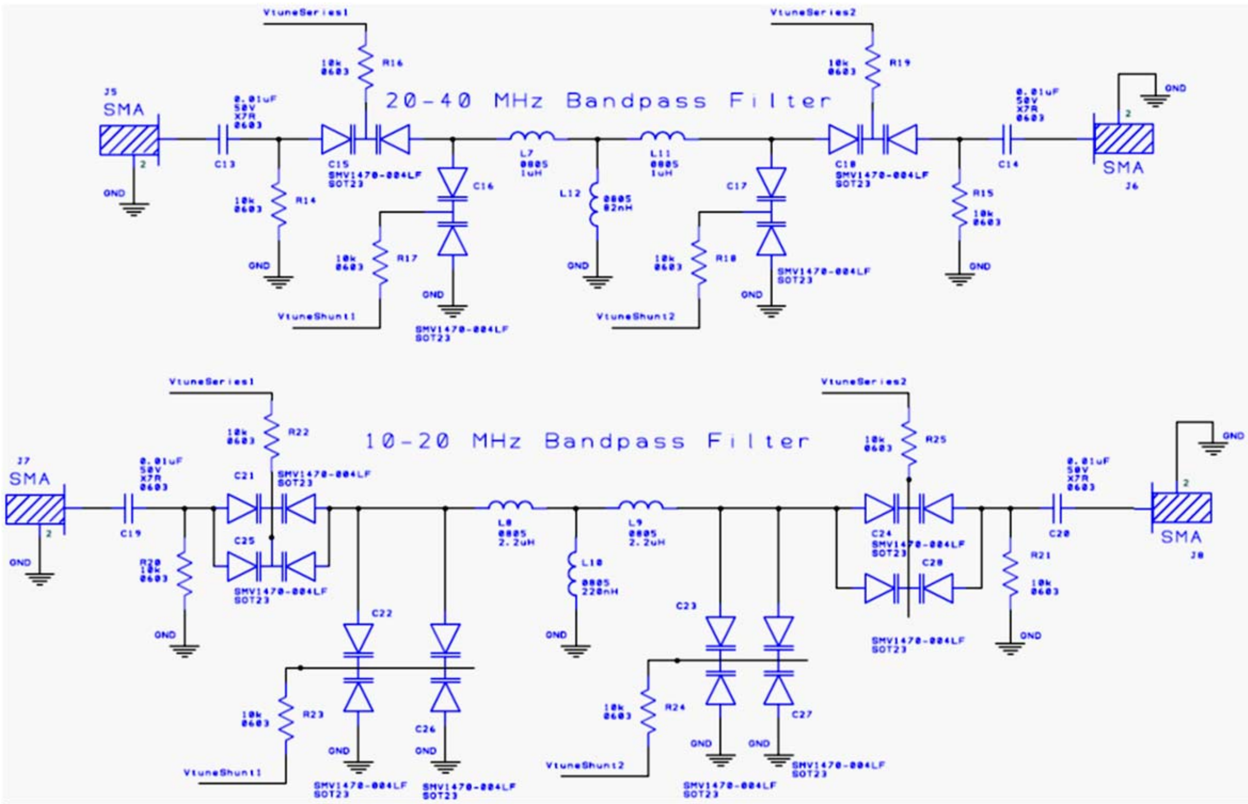


Figure 16 Wide view of Figure 15

4 Prototypeboard Schematics



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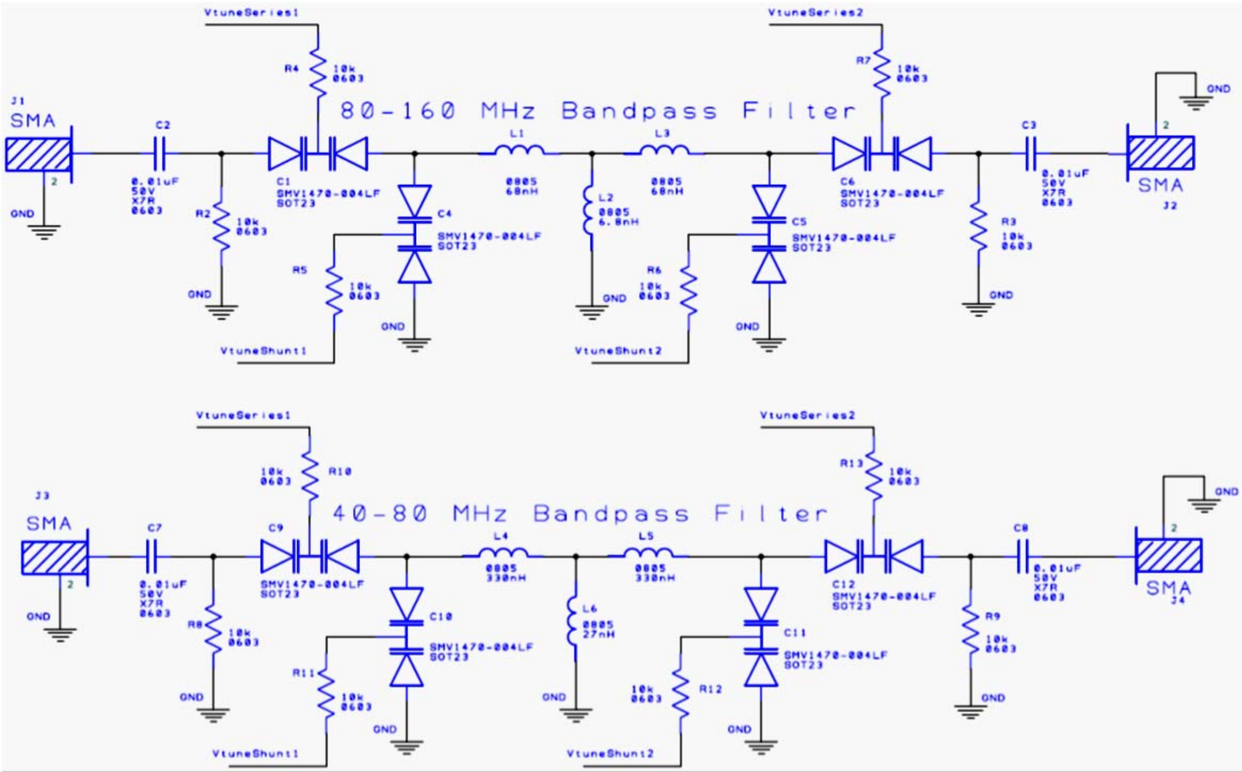

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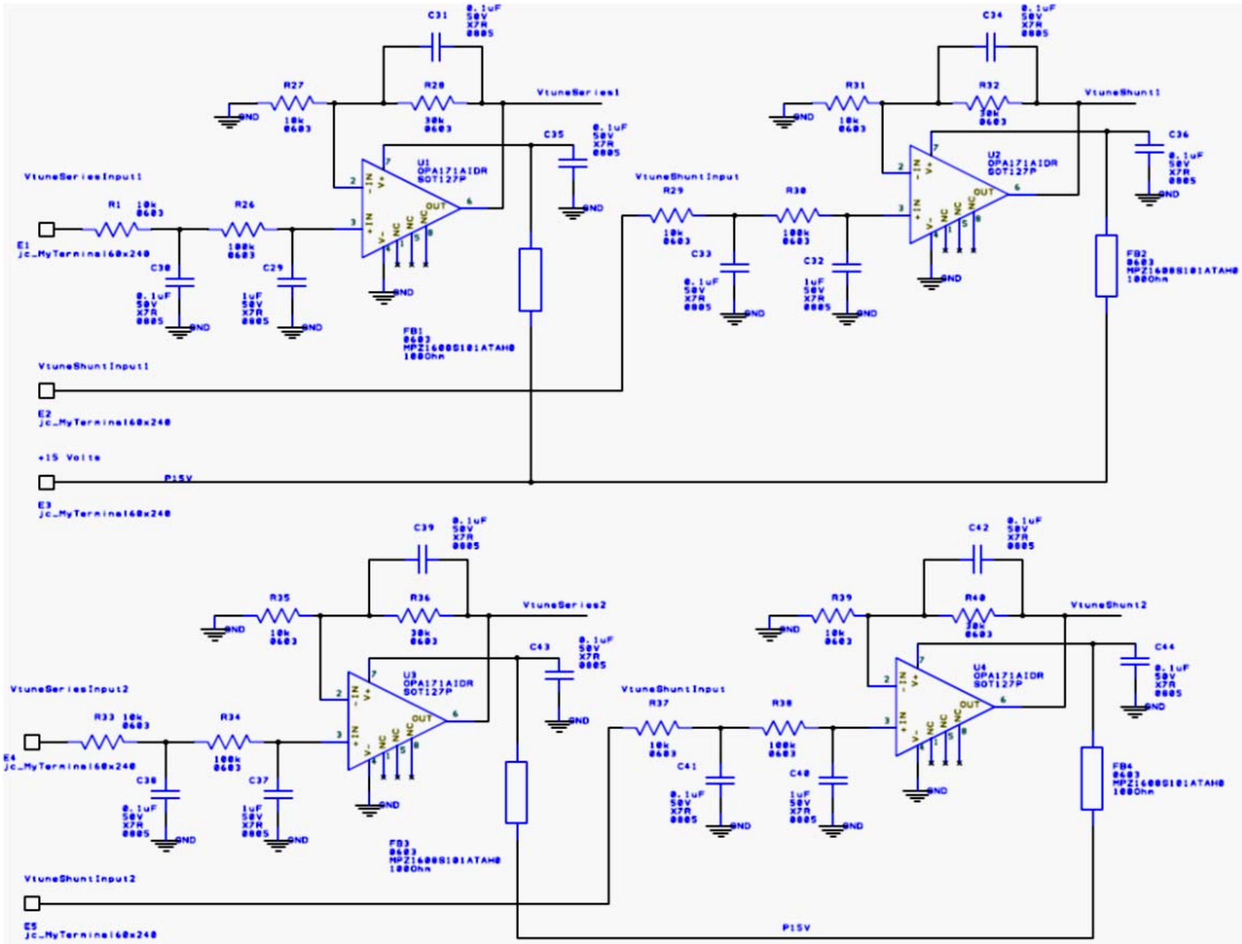

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