Instructor Notes on Johnson Noise kB experiment –

Bruce Thompson, Ithaca College - July 2013

The circuit is from Melissinos & Napolitano, 2003 but with updated op amps.

Horowitz and Hill has a good section on Johnson Noise and noise measurements.

For the first amplifier, use a good low-noise FET input op amp. The OPA134 works well. (LT1792 is good too.) Low values for the feedback resistance divider minimizes noise. A gain of 11 boosts the signal level without boosting the noise too much. Use metal film resistors.

The second op amp should also be a good low noise but now it doesn't have to be FET input. An OP27 is now a good choice. The gain of 221 brings the signal up to reasonable levels for the RMS detector. (DO NOT use an LT1028 – mucho problemo.)

The third and 4th op amps in the circuit provides a buffering of the high pass and the low pass filters. There is one high pass stage and two low pass stages. The two low pass stages could have been done with an active filter circuit but this circuit will be more understandable for student with just Ph225 experience.

When measuring the gain of the circuit, use a signal generator with a 10:1 or 100:1 voltage divider using small resistance values. Use metal film resistors (like 10K and 100 ohms). Also, be sure to measure the response to a high enough frequency that the signal is attenuated to the millivolt level. The Agilent 33220A signal generator makes it easy to set frequencies. A digital scope can used to measure the gain output. No need for automation; just take the data by hand. I set the scope to average 64 traces and then used the measure peak-peak and got good results. I also measured the gain using the Fluke 45 set on Vrms and converted to peak-peak. As the Matlab graph shows, the results were virtually identical.

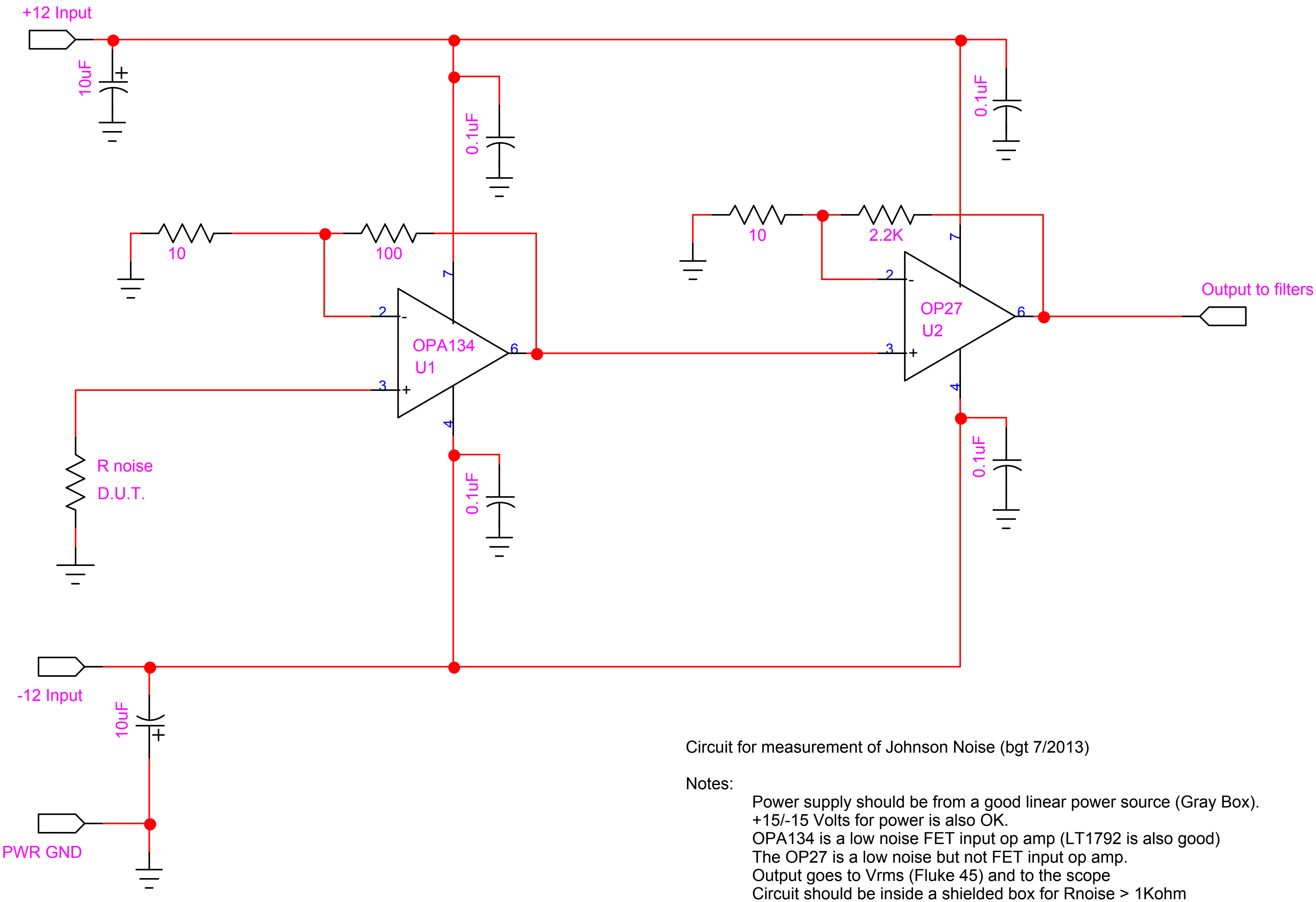
When measuring the RMS noise, use a good RMS voltmeter. The Fluke 45 works well. It can be set to integrate for longer periods of time to make the signal more stable. The RMS of an oscilloscope is not as accurate and jumps around more. No need for automation here either. Test resistance values between 0 and 15 kOhm work well.

I got a value of (1.38+/-0.02)E-23 using the scope p-p measurements and (1.40+/-0.02)E-23 using the Fluke Vrms gain measurements. I don't know if these were just luck or if it can be reproduced. Matlab file: BoltzMatlab_2013c.m

Measuring the actual room temperature can be important if working at the 1 to 2% accuracy level. In that case it is also important not to warm the resistors under test with your fingers when putting them in the circuit. A pliers is better.

The present circuit construction is a mess. It could be rebuilt with color coded power and ground; putting the DUT at the left then the preamp, then the filters; on a new breadboard so that the contacts are sure to be good.

Preamp circuit for Johnson Noise Experiment
Bruce Thompson, Ithaca College 7/2013

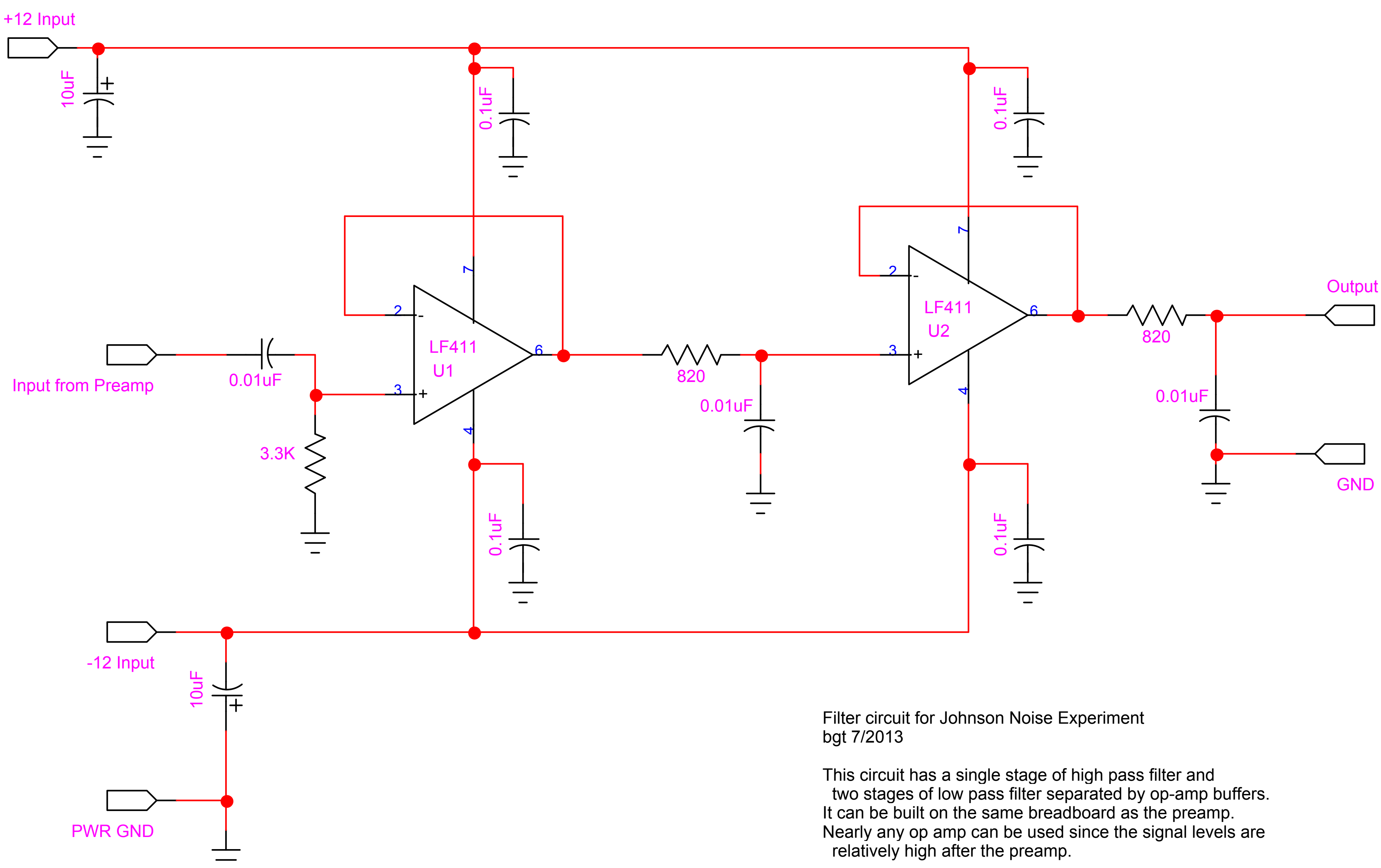


Circuit for measurement of Johnson Noise (bgt 7/2013)

Notes:

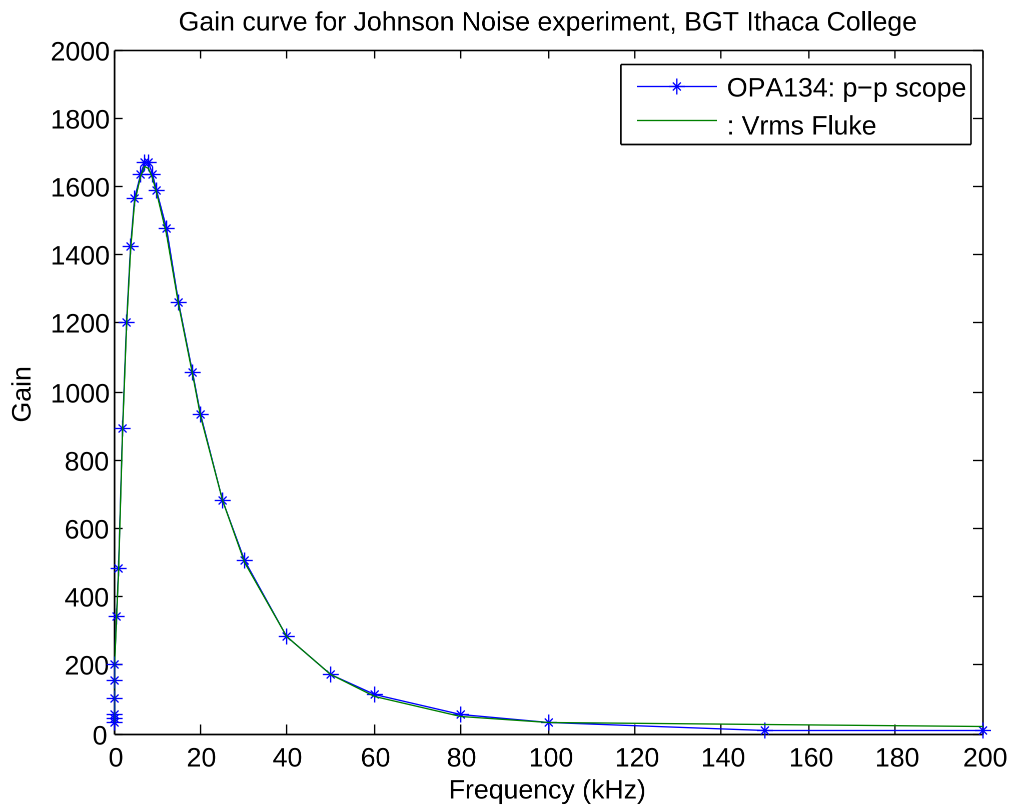
Power supply should be from a good linear power source (Gray Box).
+15/-15 Volts for power is also OK.
OPA134 is a low noise FET input op amp (LT1792 is also good)
The OP27 is a low noise but not FET input op amp.
Output goes to Vrms (Fluke 45) and to the scope
Circuit should be inside a shielded box for Rnoise > 1Kohm
Measure circuit gain using an attenuated signal generator

Filter circuit for Johnson Noise Experiment
Bruce Thompson, Ithaca College 7/2013

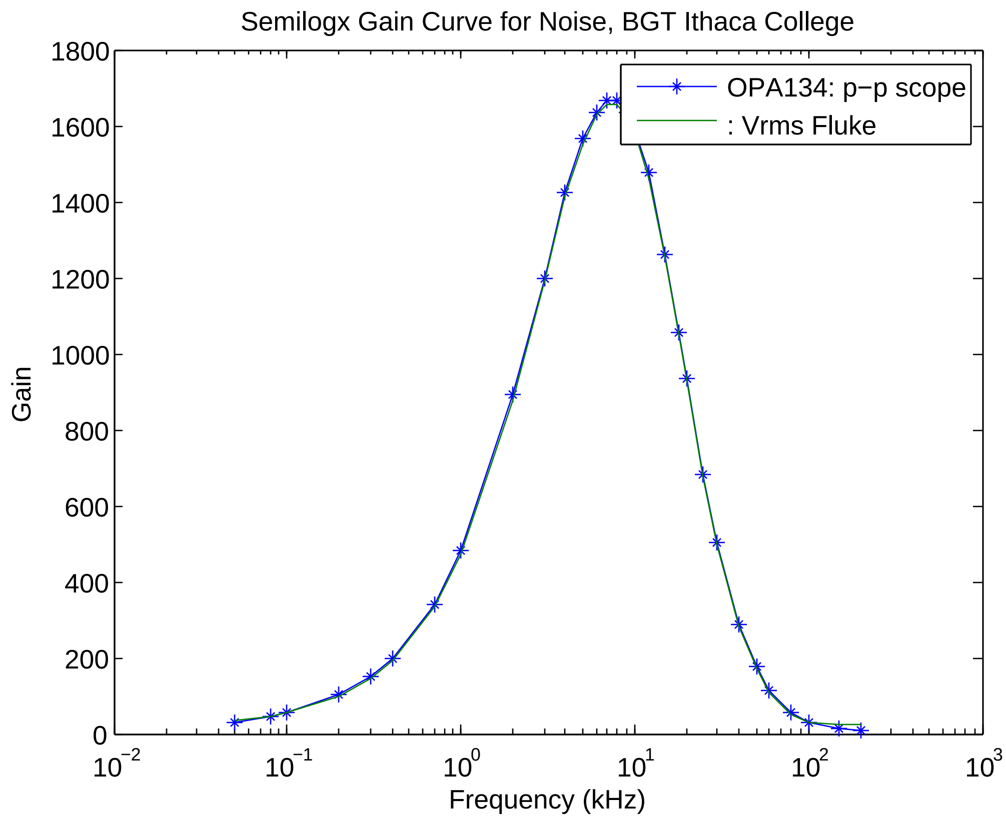


Filter circuit for Johnson Noise Experiment
bgt 7/2013

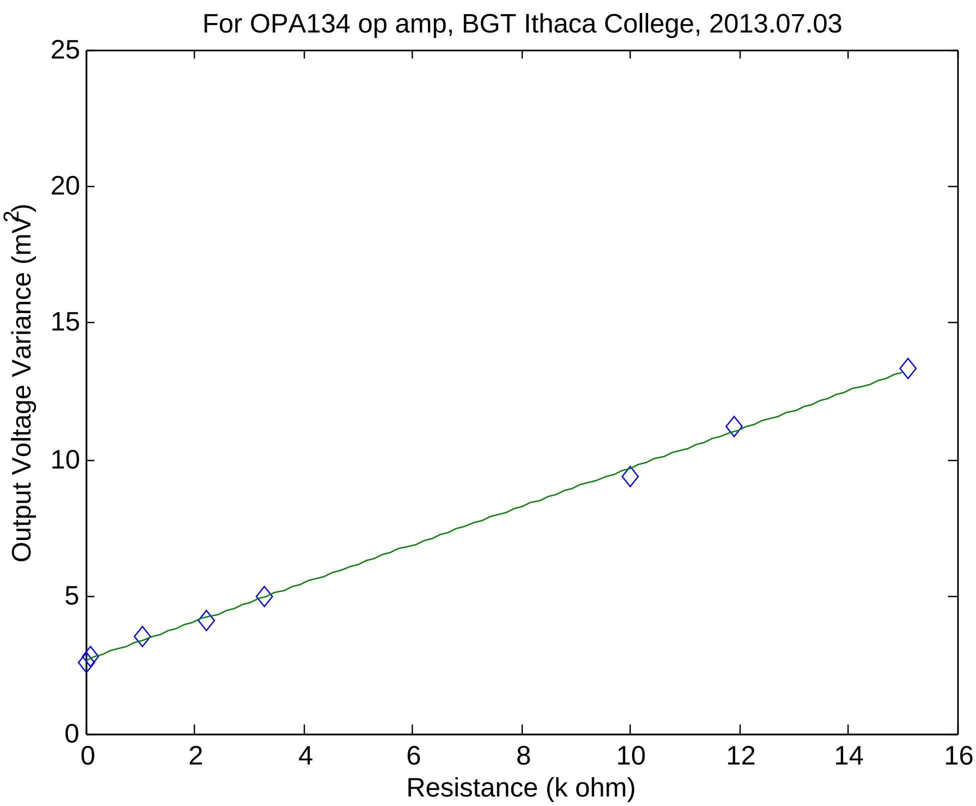
This circuit has a single stage of high pass filter and
two stages of low pass filter separated by op-amp buffers.
It can be built on the same breadboard as the preamp.
Nearly any op amp can be used since the signal levels are
relatively high after the preamp.



Gain curve for Johnson Noise experiment, BGT Ithaca College
OPA134: p−p scope
: Vrms Fluke
Gain
Frequency (kHz)
0
200
400
600
800
1000
1200
1400
1600
1800
2000
0
20
40
60
80
100
120
140
160
180
200



Semilogx Gain Curve for Noise, BGT Ithaca College
Gain
Frequency (kHz)
OPA134: p−p scope
: Vrms Fluke
0
200
400
600
800
1000
1200
1400
1600
1800
10^{-2}
10^{-1}
10^{0}
10^{1}
10^{2}
10^{3}


For OPA134 op amp, BGT Ithaca College, 2013.07.03
Output Voltage Variance (mV²)
Resistance (k ohm)
0
5
10
15
20
25
0
2
4
6
8
10
12
14
16