Looking at Dynamic Range

With only 10-bits of resolution, the digital to analog converter is the limiting element for through signal applications. We will look at the dynamic range of the Block system and how to scale signals. The state variable filter is a useful example for testing the response of the system. A Bode plot will be used to show signal limiting.

First, let's design a 200Hz bandpass filter with a Q of 10.

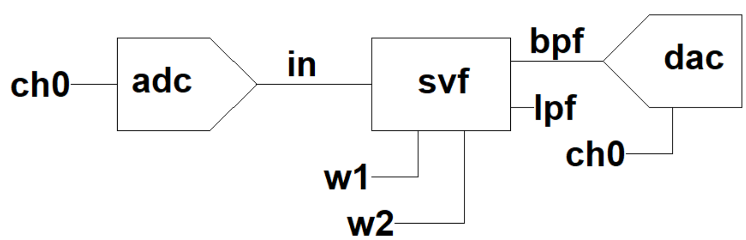
$\omega = 2\pi f = 6.283 * 200 = 1256$

$\mathcal{L} = 1/2Q = 0.05$

$\omega 1 = \omega/Q = 125.6$

$\omega 2 = \frac{\omega^2}{\omega 1} = \frac{1256.8^2}{125.6} = 12560$

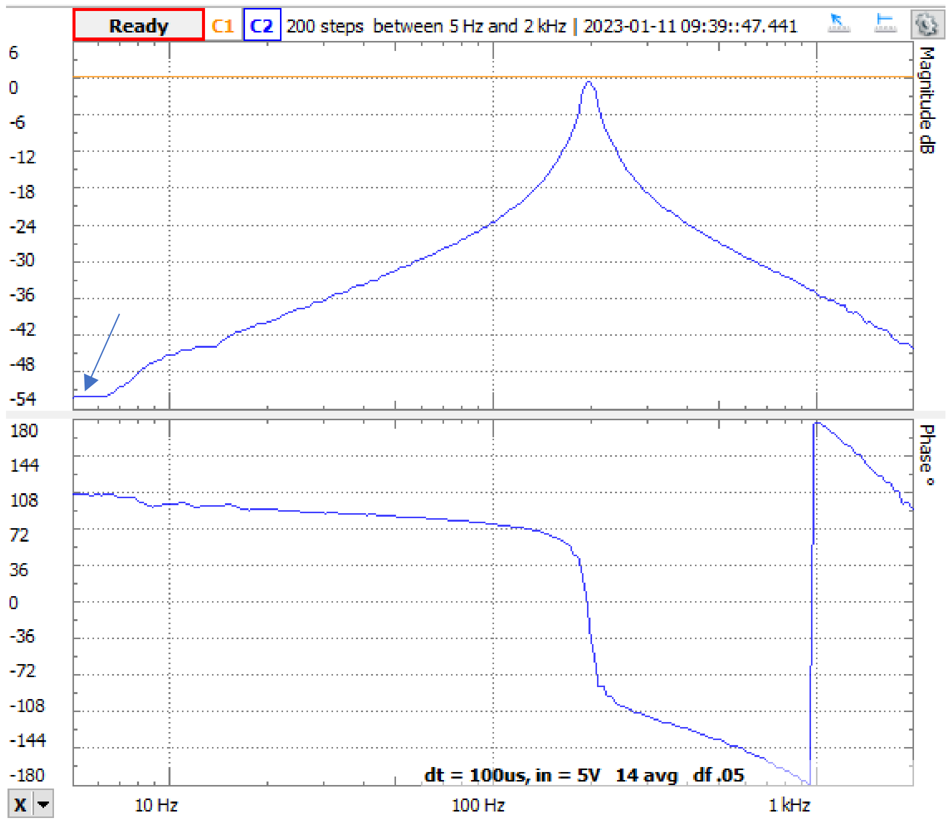
The Block program will use ADC0 for input and DAC0 for output. An external oscillator source and o'scope are needed to generate and to view the filtered signals.



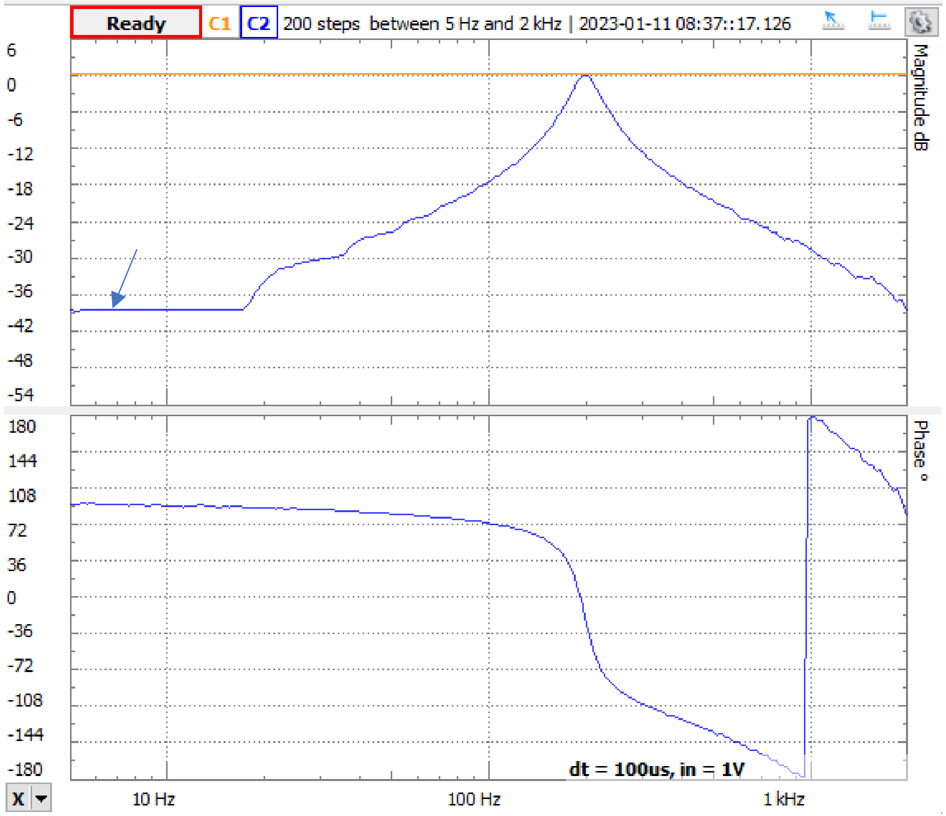

```
clr
adc ch0 in
svf in w1 w2 bpf lpf
dac bpf ch0
end
set dt 0.0001
set max 10000
set w1 125.6
set w2 12566
set avg 14
```

The dynamic range of a converter is limited by the number of steps it can divide the signal. Usually this is given in dB = 20*LOG(Vout/Vin). As you can see, it is a unitless ratio. A signal ratio doubles every 6dB and increases by a factor of ten every 20dB. A close approximation for the range of a converter is about 6dB times the number of bits. The DAC has an approximate dynamic range of 6dB*10-bits = 60dB. The ADC (with some averaging) is about 12-bits and has an approximate dynamic range of 72dB.

The voltage on the ADCs and DACs is ±10V for a range of 20V. The minimum step size for the DACs is about 20mV and the minimum step size for the ADCs is 4.88mV. To have the maximum dynamic range, the input signals and output signals need to be close to ±10V.



This Bode plot shows signal limiting at about -51dB. Only noise is present at this low level. Note that the range is just over 50dB. This is because the input signal is plus and minus 5V limiting the DAC to 9-bits or around 54dB of dynamic range.



Reducing the input signal level to ±1V, also lowers the dynamic range. Now it limits around -39dB. The equivalent number of bits is 6.7 = $\log_2(1024/10)$.

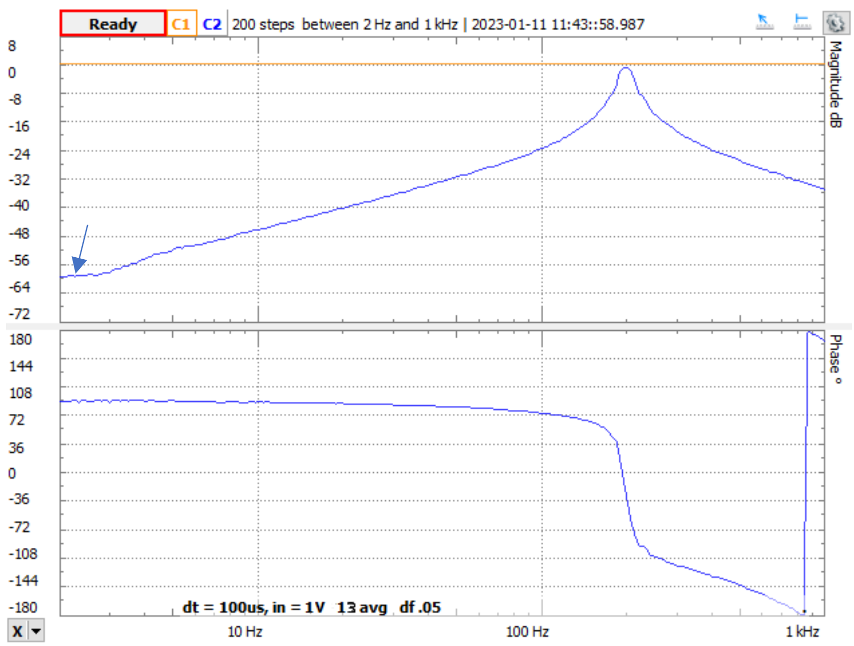
We can solve the problem one of two ways. First is to use an amplifier with a gain of 10 to boost the input signal. Second, we can use a multiply block to boost the signal. However, the output from the DAC will need reduction.

For the second approach, the Block multiply uses single precision floating point calculations. There is about 6 places of accuracy or 120dB of dynamic range for the numbers. The ADC signal will be reduced by 10 for a 1V signal and its dynamic range will lower to 8.7-bits or 52 dB of dynamic range. Averaging improves the ADC dynamic range and noise. To keep the same 10KHz sample rate, AVG is set to 13. Averaging more will affect the dt loop time.

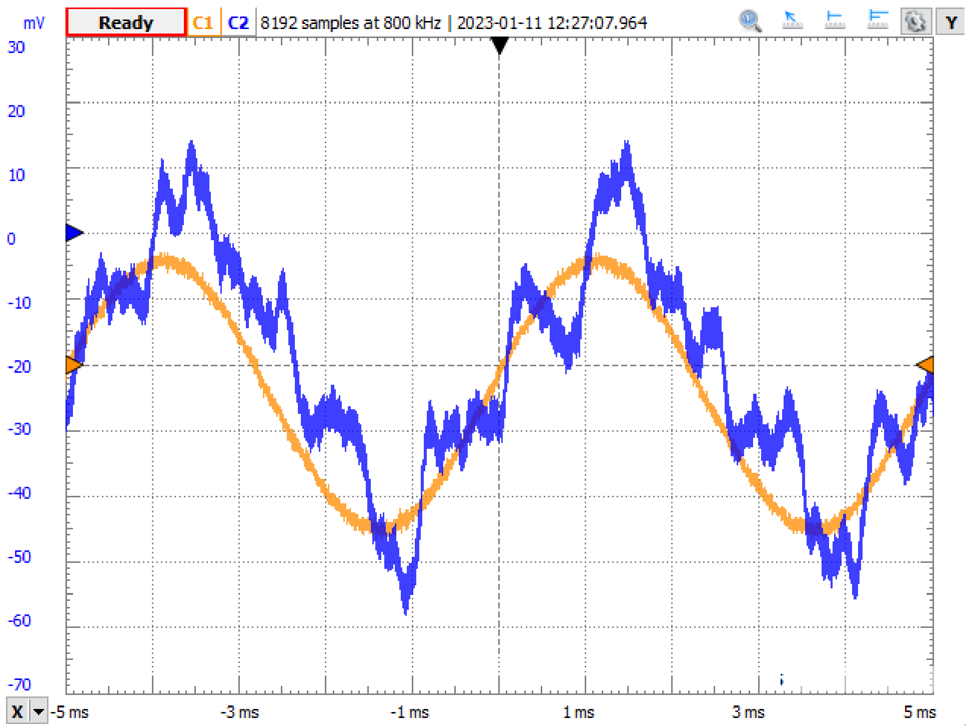
The DAC0 output can be reduced by 10 using a trimmer potentiometer. Use a 2K or larger potentiometer to keep the op amp output current to 5mA or less. One termination connected to the output pin. The second termination to ground and the wiper adjusted for the 1 volt output.

Here is the filter Block program modified to increase the output signal by ten:

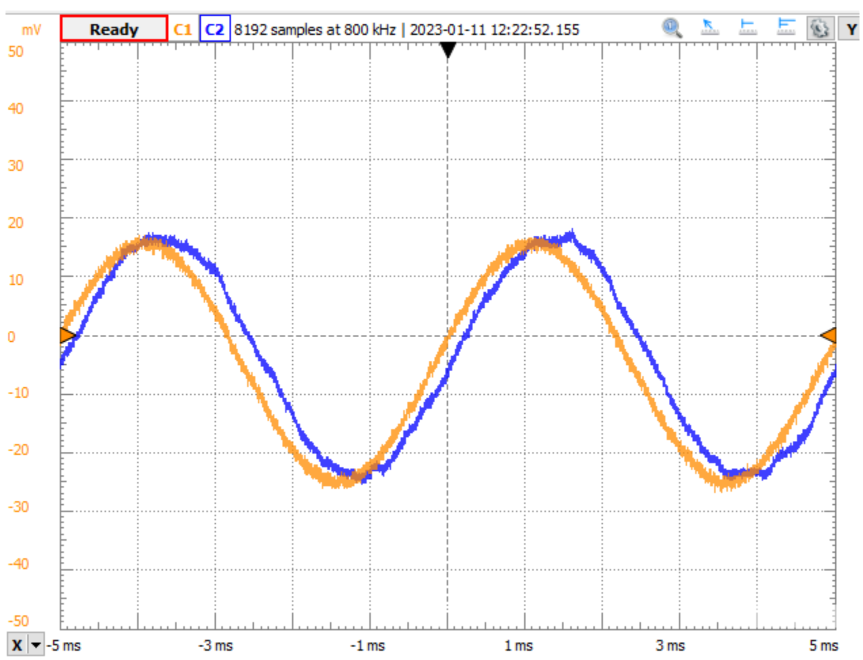
```
clr
adc ch0 in
svf in w1 w2 bpf lpf
mul bpf 10 out
dac out ch0
end
set dt 0.0001
set max 10000
set w1 125.6
set w2 12560
set 10 10
set avg 13
```



After increasing the DAC output voltage to full scale then reducing it by ten increased the dynamic range to about 60dB. This is the best analog output/input range the Block system can achieve. Input only systems can perform up to the ADC limitations which is around 72dB with a full-scale input.



The DAC0 output (blue trace) from the filter with 40mVpp input signal at 200Hz.



The DAC0 output using the 10X multiply and resistor output divider. The improvement in the quantized steps and noise is evident.