BIOPAC Systems, Inc.

42 Aero Camino
Goleta, CA 93117
Ph (805) 685-0066
Fax (805) 685-0067
www.biopac.com
info@biopac.com

#AH160 - Gas Analysis Module Response Time

A major factor affecting breath-by-breath respiratory gas measurements is the response time of the O2100C and CO2100C modules. Although the CO2100C module has somewhat faster response times than the O2100C module, both can seemingly create obstacles when performing relatively high speed breath-by-breath ventilation measurements.

Typically, the O2100C and CO2100C modules are used in conjunction with a mixing chamber and non-rebreathing "T" valve to measure varying gas concentration levels as a function of time. The mixing chamber and "T" valve effectively construct a smoothing filter for expired gases. Because the gas concentrations can change only gradually in this configuration, it is simple to monitor the changing oxygen and carbon dioxide levels present in the mixing chamber.

An alternate, and more difficult, measurement scenario is where oxygen or carbon dioxide concentrations need to be measured exactly, at particular points during a single respiration. In this case, it is very important that the module be able to keep up with the expected rate of change of gas concentration.

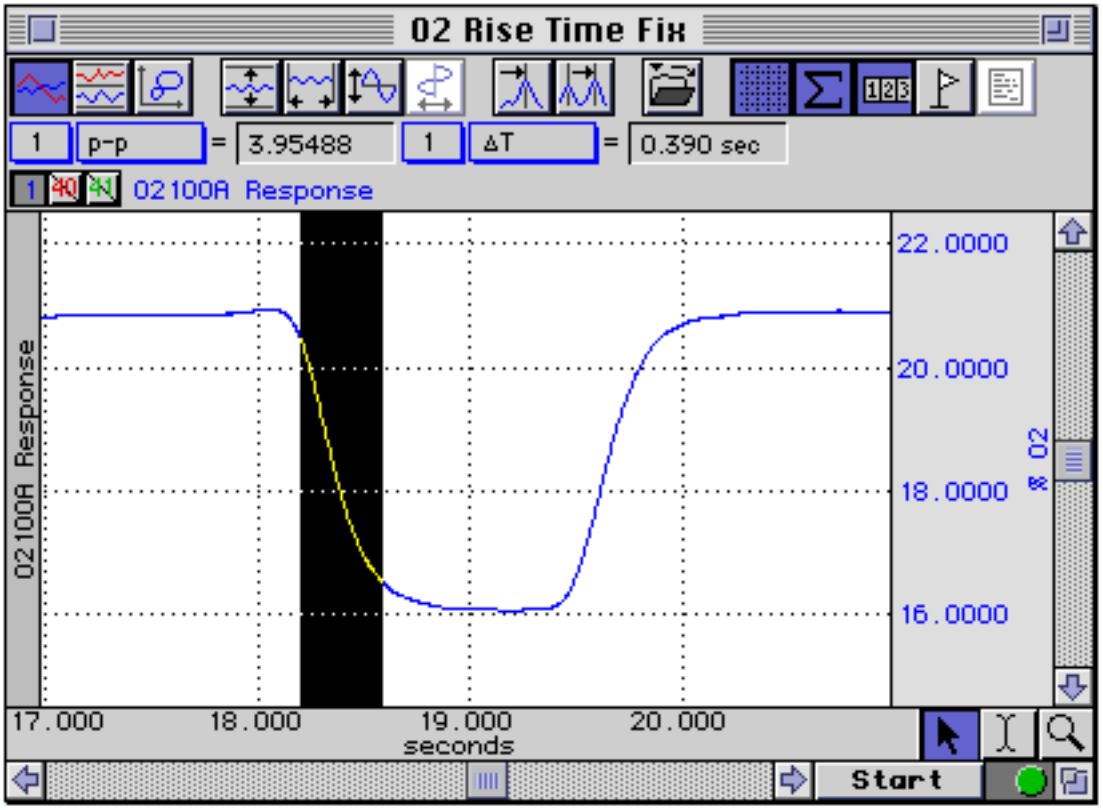
This application note will concentrate on methods to improve the response time of the O2100C module. When necessary, the same principles will apply to enhance the speed of the CO2100C module.

Nominally, the step response time of the O2100C module is 500 msec. Thus, for breathing rates exceeding 42 BPM (using the formula **Tr = 0.35/Fh** where **Tr** is Rise Time, the time for the signal to traverse 10%-90% of the total range, and **Fh** is the High Frequency limit), the O2100C module will slowly begin to attenuate its response to oxygen changes.

Technique 1

The response time of the O2100C module can be improved somewhat by increasing the sampling pump flow rate. Run at flow rates between 100 and 150 ml/min when you

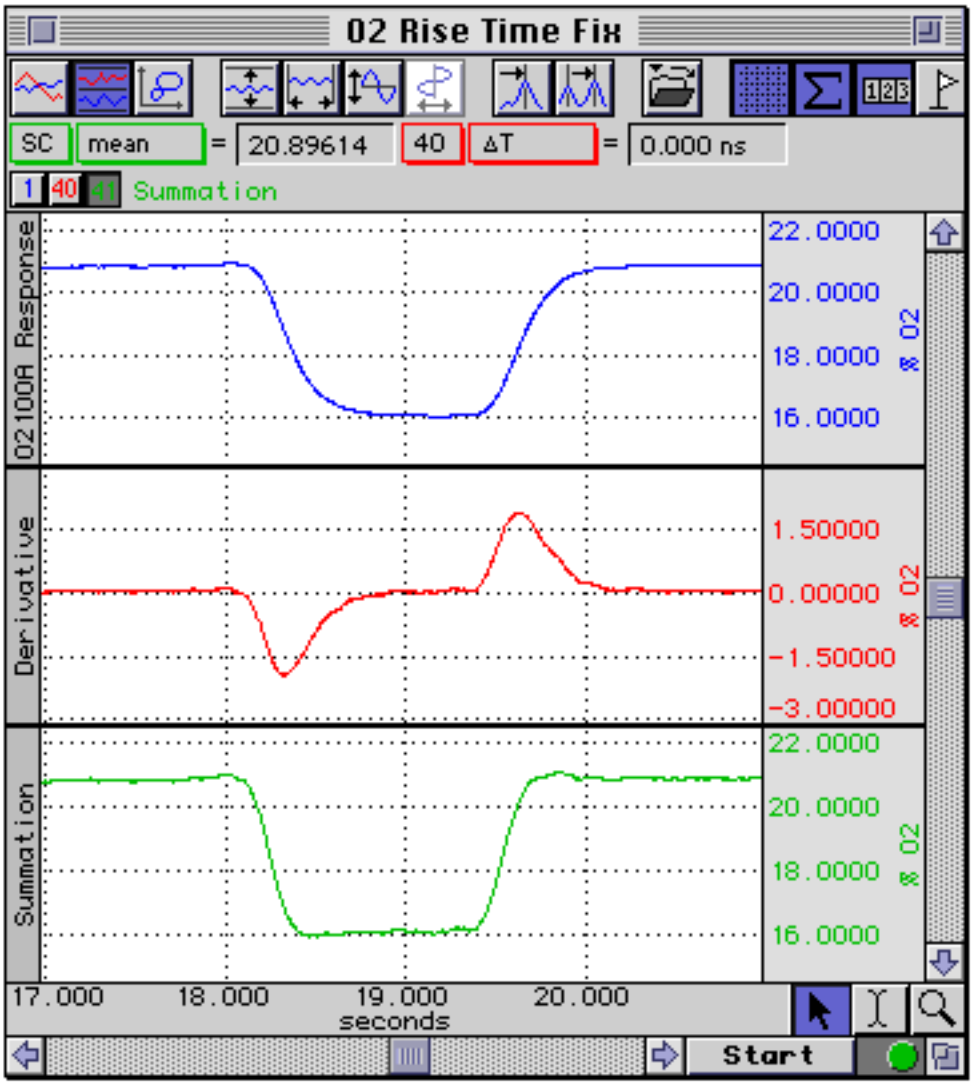
wish to improve the response time of the O2100C module. Response times can often be boosted 50% over the nominal response times of 500ms at 100 ml/min. The following graph illustrates the typical response time obtained when running the O2100C module at a flow rate of 120 ml/min. In this case, the response time of the O2100C module has been improved to 390ms, over the specified 500ms at 100 ml/min.



O2100C Module Nominal Response Time

Technique 2

To improve the response time of the module further, use the real-time calculation features in Acq*Knowledge* to create a classic "lead-lag" filter which can be applied to the module output signal to help speed up the response. Essentially, a filter is created which acts as the inverse of the mechanical filter resident in the O2100C module sampling mechanism. The following graph illustrates this software correction technique.

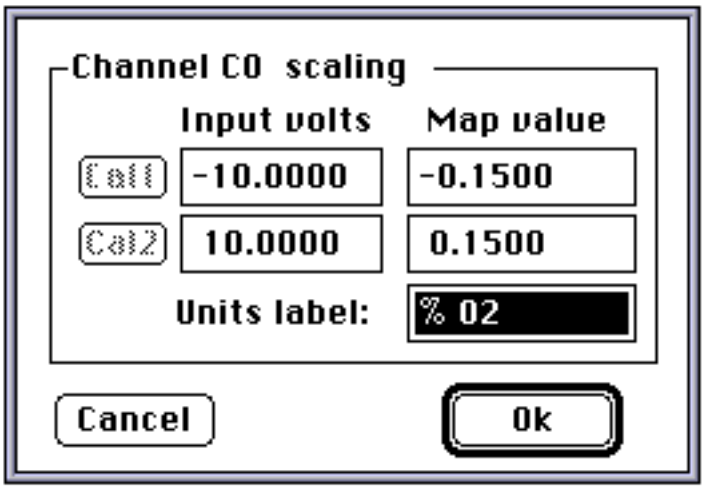


O2100C Response Time Improvement Algorithm

Explanation of Technique 2

Waveform 1 - O2100C module output signal
The "Response" waveform is the sampled O2100C module output.

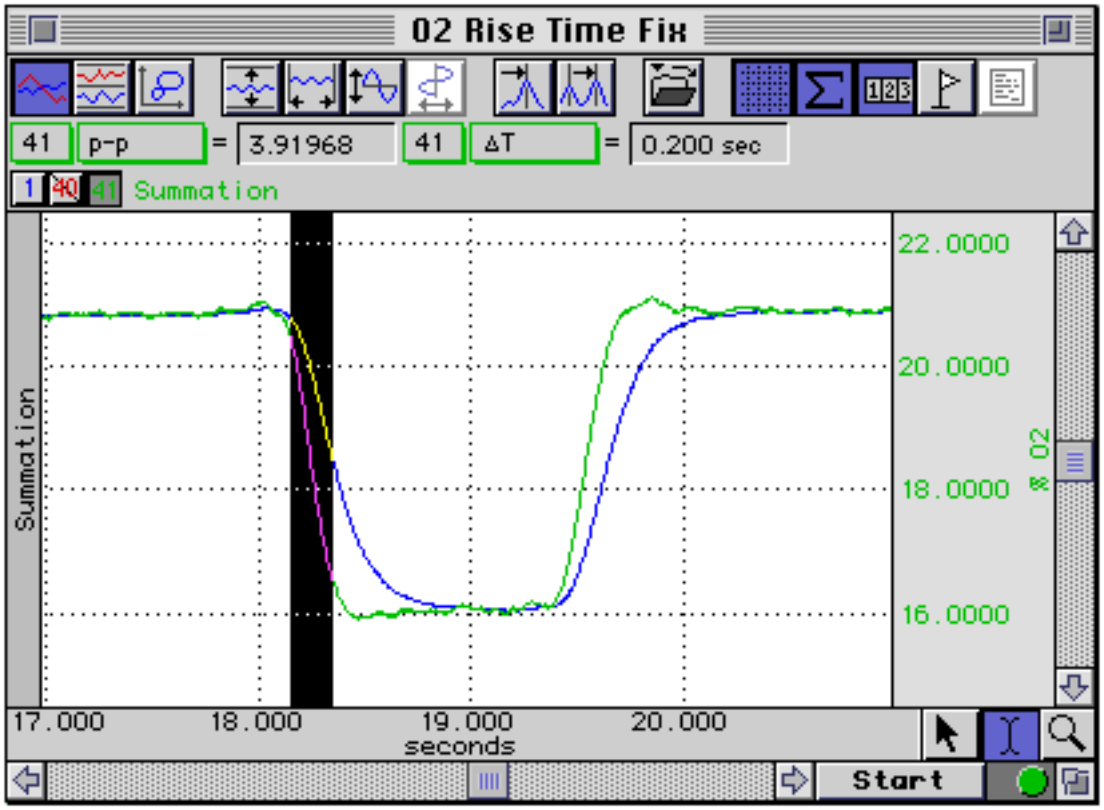
Waveform 40 - Derivative of O2100C module output signal
The "Derivative" waveform emulates a mathematical derivative on Waveform 1, in real time. The derivative has been implemented as a 10 point running difference, with scaling factors adjusted as follows:



Waveform 41 - Summation
The "Summation" waveform is the summation of Waveform 1 and Waveform 40. The original is added to its scaled derivative in order to improve overall response time. This technique functions because the response characteristics of the O2100C module are stable and linear.

Finally, when directly comparing the response time of the original versus the corrected outputs, a factor of two improvement in performance is noted. The rise time of the uncorrected module output is 390ms. As shown in the following graph, the response improved output shows a modified rise time of 200ms.

When calculating for maximum breathing rates measurable with the response improved output, the formula **Tr = 0.35 / Fh** indicates a maximum rate of 1.75 Hz or 105 BPM, prior to the point where the O2100C module will start to attenuate its response.



O2100C Response Time Improvement

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