

Model 1020 Interfacing Guidelines

Overview

The primary application for the Model 1020 Pulse Plethysmograph is to measure pulsatile blood flow changes in the skin of human or animal subjects. This briefing paper is designed to help you interface the Model 1020 to an amplifier, whether the latter is a dedicated circuit for the 1020 or perhaps the front end of a third-party recorder.

The Model 1020 has three electrical connections: excitation (white wire), signal output (black or blue wire) and ground (cable shield). The excitation lead provides a power supply for an Infrared LED; the LED is in turn connected to ground through a small series current-limiting resistor. Excitation voltage should be 5 to 9 volts DC for best results.

The signal output, which is internally buffered to preserve signal quality, should be connected to an amplifier of some kind. The sections below discuss the filter circuits needed between the Model 1020 and your amplifier. Finally, the ground lead provides an electrical return path that is shared by the excitation and output signal circuits.

Since the Model 1020 supplies only one output signal, a differential amplifier is not required -- a single-ended type is sufficient. A differential amplifier *can* be used, however; this is convenient, since they are much more common than the single-ended variety. When a differential amplifier is used – and this is the type shown in the example circuits below -- the unused (inverting) input must be connected to ground (more about this later). If a single ended amplifier is used, the inverting input can be ignored, since there are no connections to it.

The circuitry required to interface the Model 1020 to most amplifiers and recorder systems is not complex. In fact, we have found that the required components usually fit inside the amplifier input connector!

1020 output signal components

The Model 1020 output signal has two components:

- 1) a DC *baseline* component correlated with the average light level reflected by the tissue under the transducer;
- 2) a much smaller *pulsatile* component that normally increases with the flow of blood into the tissue under the transducer, then decreases as blood flows out. This pulsatile blood flow, and therefore the pulsatile signal component, correlates strongly with heartbeat.

Just how you interface the Model 1020 to your downstream equipment depends entirely on which component, pulsatile or average, you wish to detect.

Pulsatile configuration

Capacitive coupling between the Model 1020 signal output and your amplifier or recorder will block the DC baseline component and allow to pass just the pulsatile signal. The 1020 is most often be interfaced in this manner.

To implement this approach, first connect a capacitor between the 1020 output and the amplifier input (Figure 1). Second, add a resistor between the amplifier input and ground -- this ensures that the signal is properly referenced. These added components constitute a *high-pass filter*; the values must be chosen carefully so that the pulsatile signal is not blocked along with the baseline component.

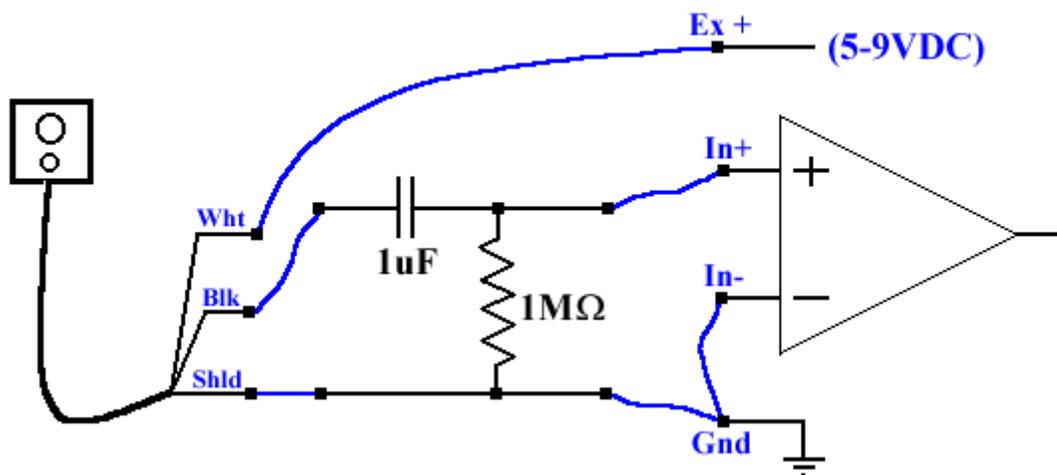
In the example circuit below, in which a 1 uF capacitor and a 1 megohm resistor are used, the roll-off frequency is 0.16 Hz. That is, below 0.16 Hz, the output signal will be reduced progressively, or “roll off,” as frequency decreases. The 0.16 Hz roll-off value is low enough for most applications. However, a higher value can be used if 0.16 Hz results in too much baseline “wandering.”

You can use the following formula to derive the proper capacitor (C) and resistor (R) values for a given roll-off frequency, f:

$$f = 1 / 2\pi RC,$$

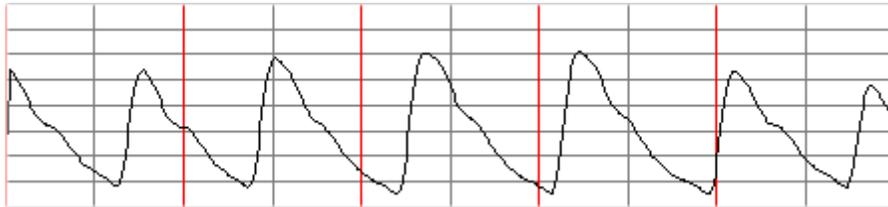
where f is in Hertz, C is in microfarads (uF) and R is in megohms.

Figure 1 -- 1020 Interface for Pulse Sensing



The Model 1020 typically outputs a 20-50 millivolt peak-to-peak signal for human subjects. If your amplifier gain is about 100, you will then have a final output of 2 to 5 volts. This is usually sufficient to drive any downstream instrument. (In fact, you may need to adjust the gain down for some applications – a quick web search on “non-inverting operational amplifier” will show you how to do this with just an adjustment in one or two resistor values.)

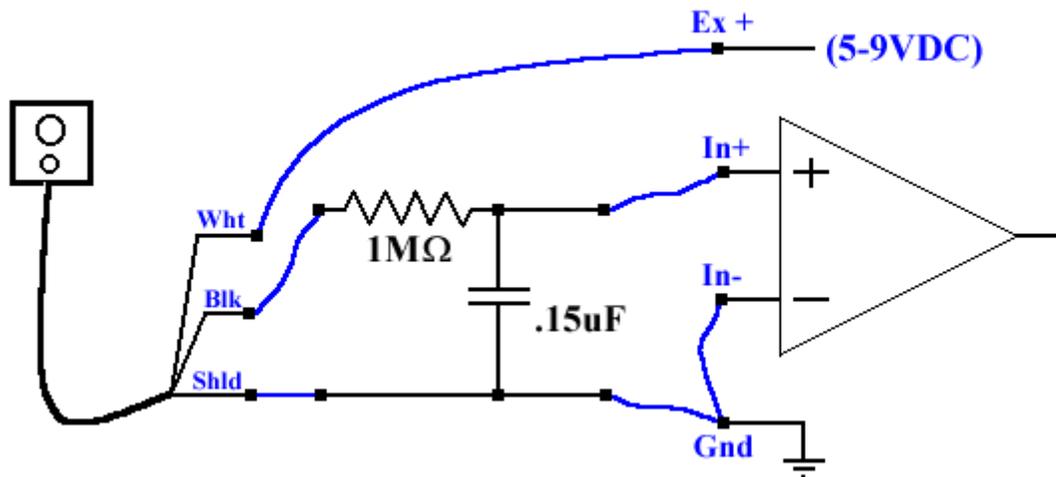
The sample data below was recorded from the finger of an adult male using our standard Model 1020 and the capacitor-coupled interface just described. The UFI Model SRS2000 performed the signal conditioning and data recording.



Average reflection configuration

In rare cases -- to monitor blushing, for example -- average reflected light might be the Model 1020 output component of interest. Here, a *low-pass filter* is required to remove the higher-frequency pulsatile signal (Figure 2). For this filter, just swap the positions of the capacitor and resistor in the previous circuit.

Figure 2 -- 1020 Interface for Average Level



Just in case you're curious, you can think of this circuit as a pipe (R) for which the flow rate (electrical current) is set by the resistor value and the water pressure (voltage at the black wire and resistor junction). The pipe empties into a broad tank (C) for which the capacity is set by the capacitor value. The voltage across the capacitor -- and so the amplifier input voltage -- corresponds to water level in the tank.

With an actual water tank, rapid fluctuations in the water pressure to the pipe cause only very small fluctuations over time in the tank water level (unless the tank is very tall and narrow). Just so with the output from the low-pass filter – high frequencies are greatly attenuated. As with the high-pass filter, the resistor and capacitor values must be chosen carefully. Now the goal is to ensure that the filter roll-off frequency is well *above* the highest rate of change in the reflected light level that you wish to observe.

In the circuit shown in Figure 2, a 0.15 uF capacitor and a 1 megohm resistor give a 1 Hz high-frequency roll-off value. That is, this circuit filters out changes in the input signal that occur *faster* than 1 Hz. The formula that interrelates frequency, resistance and capacitance is the same as that for low-frequency roll-off:

$$f = 1 / 2\pi RC,$$

where f is in Hertz, C is in microfarads (uF) and R is in megohms.

Differential amplifier use

The Model 1020 requires only a single-ended amplifier for proper operation, but as mentioned, an amplifier with a differential input configuration *can* be used. With a differential-amplifier configuration, the black lead from the Model 1020 should be connected through the appropriate filter to the non-inverting input. As shown in the example circuits, the unused (inverting) input should be connected to ground to supply it with a known and stable voltage.

There is a possible glitch, however, when this is done with the capacitor-coupled configuration (high-pass filter): excessive *offset* errors may result. That is, the amplifier input may become unbalanced so that the output no longer reflects the input signal fluctuations usefully. (In fact, the amplifier output can become “pegged” at its maximum or minimum value so that the desired signal is not visible at all.)

If you suspect an offset error of this sort, the best solution is to insert a resistor between the unused input (the inverting one, usually) and ground. The resistor value should match the one between the other, in-use input and ground (1 megohm in the example above).