ISim Lab 6 : Glucose Meter

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1 Voltage Source

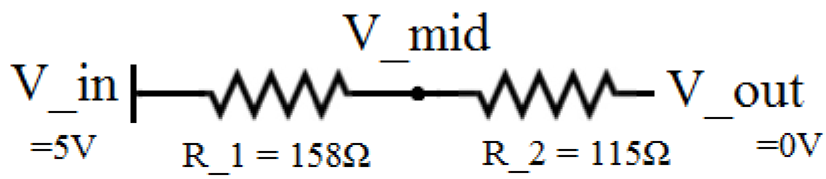

Figure 1: A simplified diagram of the circuit; the Op-Amp is not represented in the diagram, as it is assumed not to draw any current.

A quick analysis of the circuit shows that:

$$\frac{V_{mid} - V_{in}}{R_1} = \frac{V_{out} - V_{mid}}{R_2}$$
$$\frac{2.1V - 5V}{R_1} = \frac{0 - 2.1V}{R_2}$$
$$\frac{R_1}{R_2} = \frac{2.9V}{2.1V}$$

since $\frac{2.9V}{2.1V} = 1.381$ and $\frac{158\Omega}{115\Omega} = 1.374$, which shows a mere 0.5% deviation, I used the two resistors; the corresponding circuit provided the Voltage of $2.104V$ as the value for V_{mid}, consistent with the prediction.

2 Resistance Measure

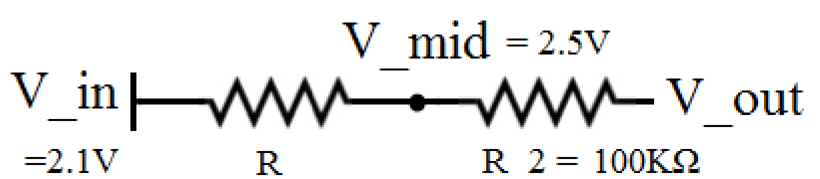

Figure 2: A simplified diagram of the circuit; the Op-Amps are, again, not represented, for simplicity. However, the values of V_{in} and V_{out} are affixed at $2.1V$ and $2.5V$, respectively, due to the Op-Amps.

Since the current through the two resisters ought to be equivalent,

$$\frac{V_{mid} - V_{in}}{R} = \frac{V_{out} - V_{mid}}{R_2}$$
$$R = R_2 * \frac{V_{mid} - V_{in}}{V_{out} - V_{mid}}$$

which, in this case, yields $100K\Omega * \frac{(2.5V-2.1V)}{(3.26V-2.5V)} = 52.6K\Omega$. As the prescribed value for the resistor was $50K\Omega$, the % Discrepancy of the two is a mere 5.2%. The following table summarizes the accuracy – and the overall characteristic – of this circuit:

Table 1: Actual(R_a) vs. Theoretical(R_t) Resistance

V_{out}	R_a	R_t
$3.306V$	$49K\Omega$	$49.63K\Omega$
$4.526V$	$20K\Omega$	$19.74K\Omega$
$4.974V$	$2K\Omega$	$16K\Omega$
$4.974V$	0Ω	$16K\Omega$
$2.572V$	$499K\Omega$	$555K\Omega$

It is readily apparent that the values are most coherent in the range that is within a modest leeway from $100K\Omega$; the values taken at extremity are less credible and demonstrate greater deviation from the actual values of the resistors.

For instance, a quick calculation of $R_{low} = \frac{(2.5V-2.1V)*100K\Omega}{5.0V-2.5V}$ proves that the resistor value lower than $16K\Omega$, the point at which V_{out} gets stuck in the rails of the Op-Amp, cannot be expected to be consistent with the theoretical values, which is indeed the case for the measurements taken at $2K\Omega$ and 0Ω(wired connection without a resistor).

As this data is closely coherent to such predictions – displaying "bound" behavior at extremity and more consistency around the $100K\Omega$ region – I can conclude that the circuit is functional.

3 Integrator

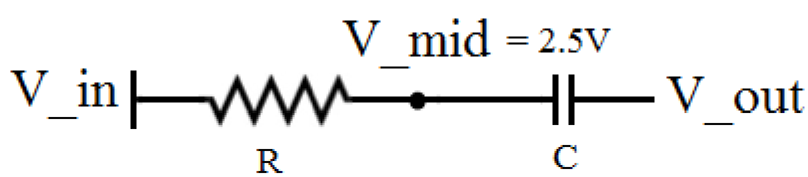

Figure 3: A simplified diagram of the circuit; V_{mid} is held to be at $2.5V$ due to the Op-Amp.

The relationship in this circuit is quite straightforward:

$$\frac{V_{mid} - V_{in}}{R} = C\frac{d(V_{out} - V_{mid})}{dt}$$

taking V_{out} as reference, the equation can be further simplified:

$$\frac{-V_{in}}{R} = C\frac{dV_{out}}{dt}$$
$$\int_0^t \frac{-V_{in}}{R}dt = \int_0^t C dV_{out}$$
$$V_{out} - V_{out_0} = \frac{\int_0^t -V_{in}dt}{RC}$$

Now, since V_{in}, is a square wave, which can be assumed constant over a brief time span,

$$V_{out} - V_{out_0} = \frac{-V_{in} * t}{RC}$$

With such relationship in mind, let us consider the following plot, generated from the experiment:

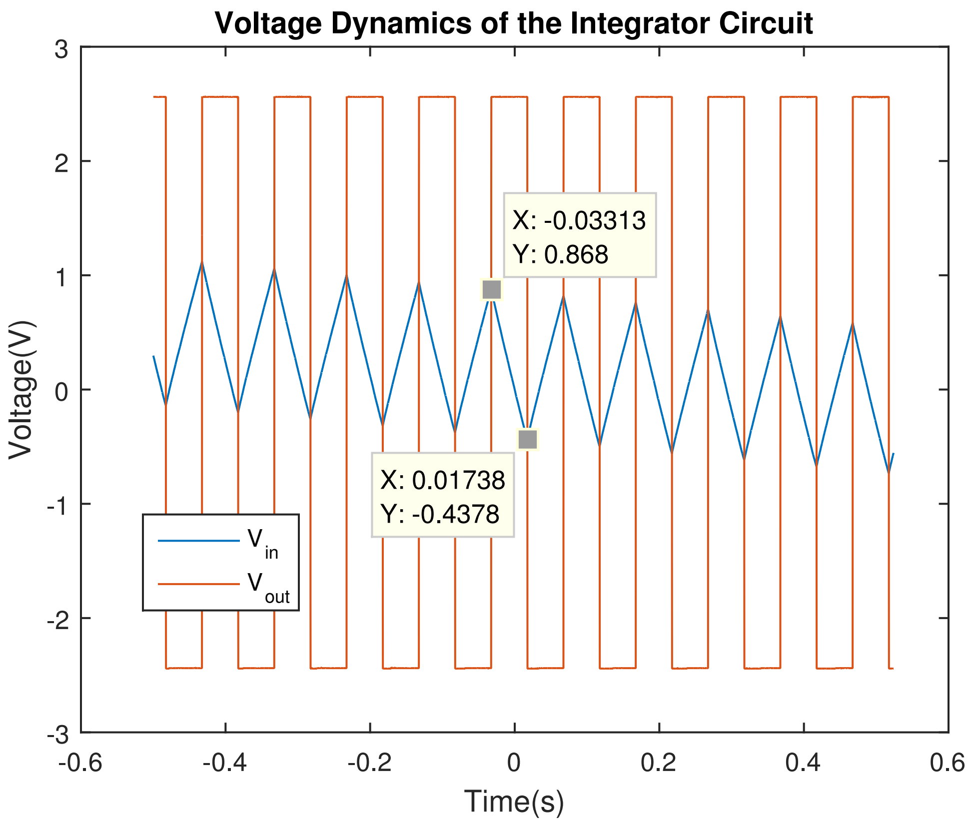

Figure 4: The Voltage Dynamics of the Integrator Circuit. The Slope is present in the graph because the snapshot was taken before the balance settled down; this choice was inevitable, as the integration was cut off prematurely by the -2.5V limit rails when the equilibrium state was reached.

Here, Δt is $0.01738 - (-0.03313) = .05051$ seconds, and $\Delta V_{out} = -0.4378 - 0.868 = -1.3058$. Theoretically, since $\Delta t = 0.05051$ seconds, $\Delta V_{out} = -2.5 * .05051/(100K\Omega * 1\,\mu\text{F})$; so the theoretical $\Delta V_{out} = -1.263V$, which is only 3.4% away from the experimental value. This coherence demonstrates that the circuit is in fact an integrating circuit.

4 Glucose Sensor

The superimposed plot of the Voltage(which is proportional to the current) over time is shown below:

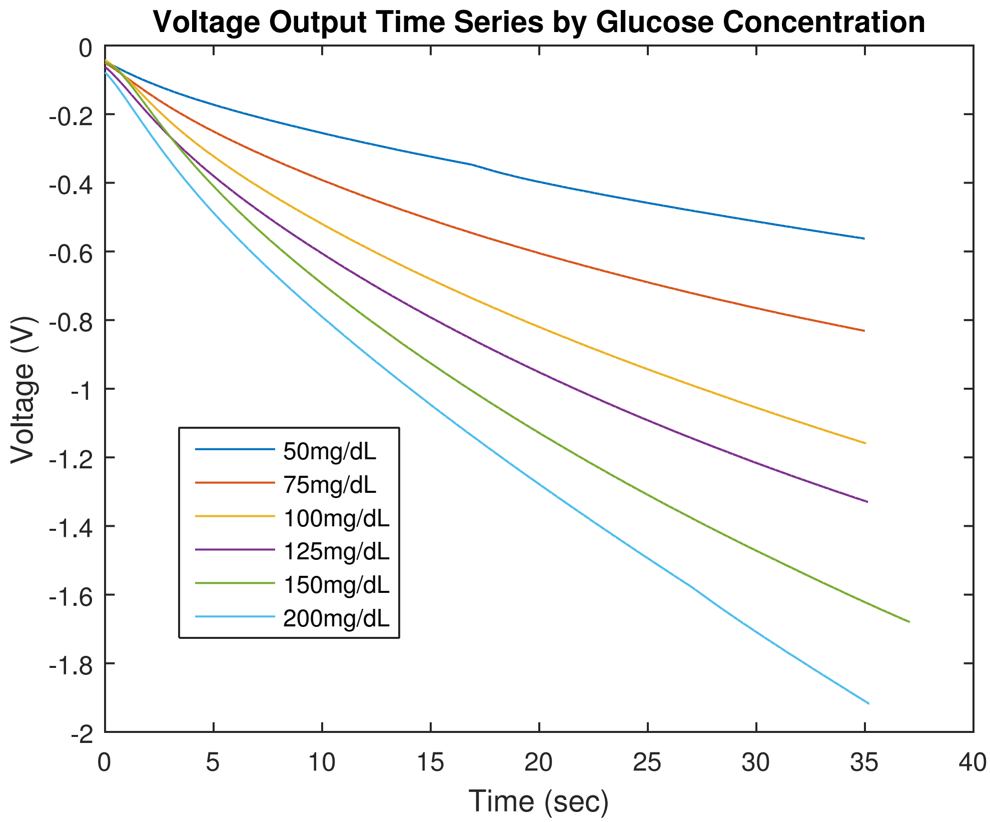

Figure 5: Voltage output time series. In superimposing the respective plots, the data was processed so that the plateaued region would be eliminated; thereby, each interaction would start at the same moment, giving a better idea of calibration.

as the trends reveal, the concentrations diverge at a slope that is approximately proportional to the concentration of glucose; this trait allows for the calibration curve to be generated, as the data themselves get spaced out over time. Accordingly, the calibration data taken at t = 25 seconds in the graph is shown below:

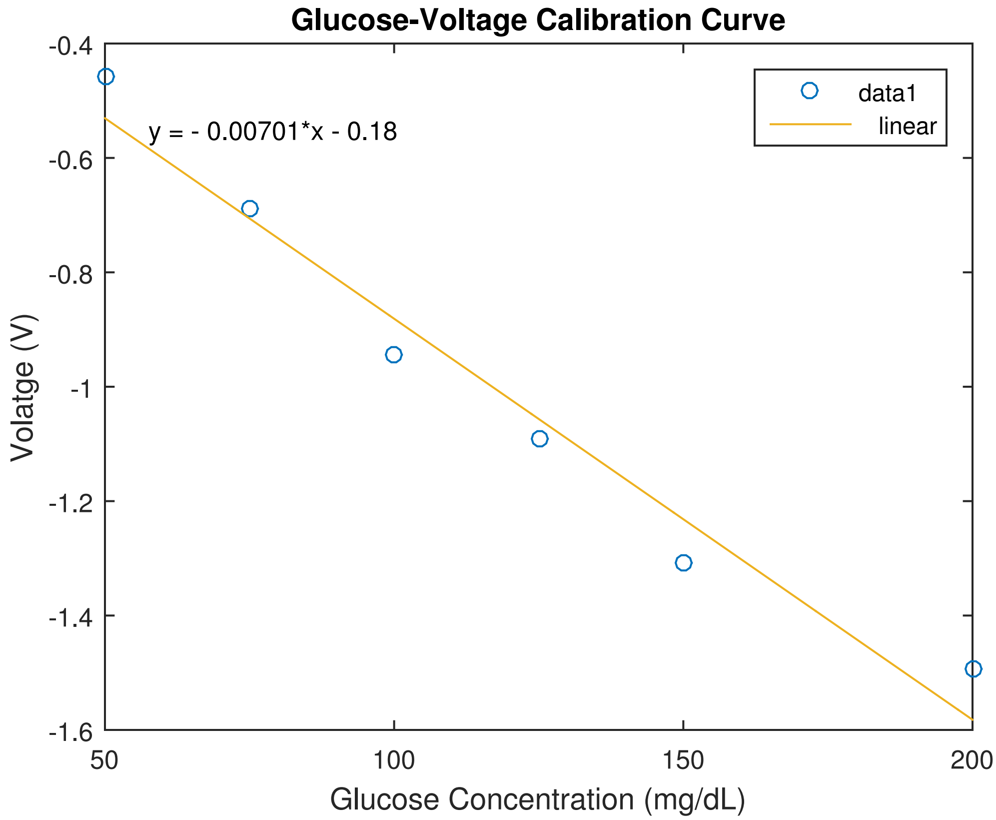

Figure 6: The calibration curve of the Voltage value per Glucose concentration, as taken 25 seconds after the beginning of the interaction.

As seen, the concentration of glucose and the voltage level are linearly dependent. The following figure also depicts the integrated value of the voltage:

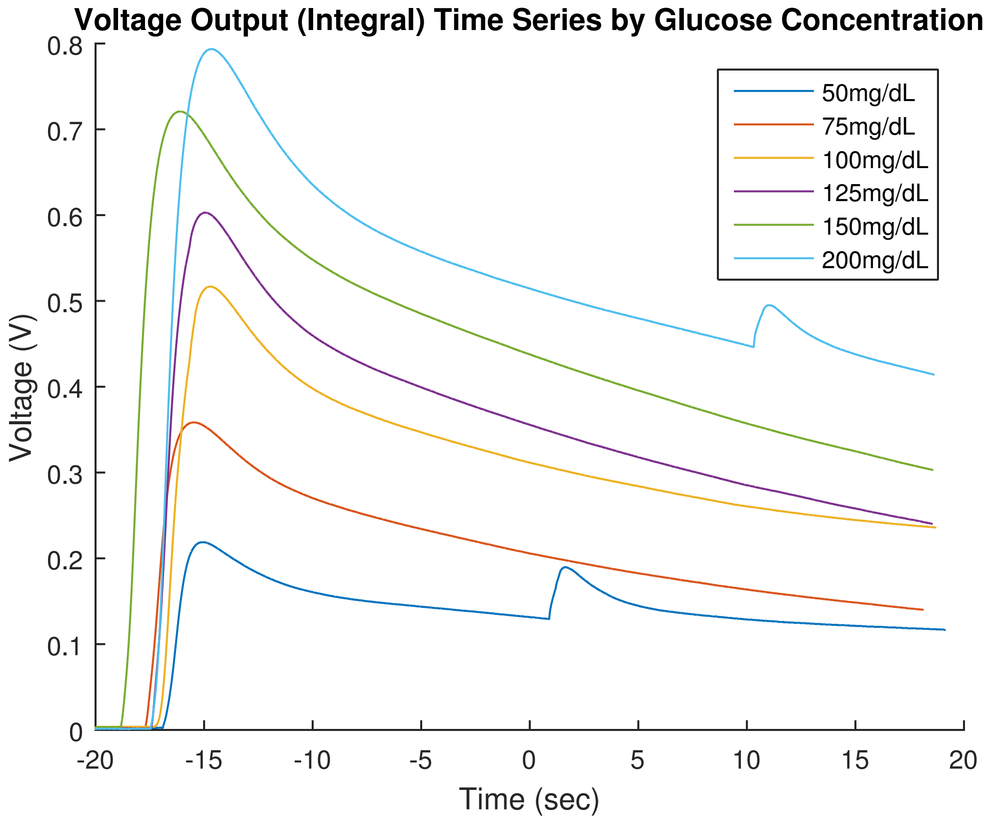

Figure 7: The integrated value of the voltage.

As seen, the fluctuations are much more exposed, thereby rendering it a poor candidate in terms of gauging the calibration.