1 Voltage Clamp

In order for a system to be voltage-clamped, the system must have the following properties. Given a voltage of the system $V_s$ and a target voltage $V_i$ the voltage clamp must provide a restoring current whenever $V_s$ deviates from $V_i$. In other words, we must have a current $I$ entering the system such that

$$ I = g (V_i - V_s). $$

In this equation, we implicitly assume that $g$ is a monotonic function of a real number $x$, passes zero at zero, and behaves as a high-gain amplifier. We propose one simple circuit which is capable of doing this.

![Figure 3. Voltage Clamp Setup](image)

This circuit has the ability to monitor the current system voltage and the current influx to the system, making it useful in a number of experiments. It is similar to the original designs used by early investigators of neuroscience.

2 Current Clamp

In a current clamp experiment, we are interested in keeping the current into a system constant. However, the only measurements we are able to make are those of voltage. So, using the voltage measured across the system, we must be able to make a determination of the current entering the system.

Let us denote the system voltage by $V_S$ and the current entering the system by $I_S$. Then we have the relation

$$ V_S = \int I_S(t) \, dt. $$

1
Now, we would like to understand how we can measure this. In essence, we would like to have a differentiator. We can find such a device in an inductor. Let us see why. Consider the following figure:

This is a simple current clamp. Let us determine the values for the required resistors and input voltage. We take the view that we can choose $R$ and $L$, and are required to solve for $R'$.

Clearly, the current through the inductance branch is given by

$$I_M = \frac{V_S}{R}$$

while the voltage across the inductor is given by

$$V_L = L \frac{dI_M}{dt} = \frac{L dV_S}{R \ dt} = \frac{L}{R} I_S. \quad (4)$$

Now, if our objective is to provide a steady current of $I_0$ to the system, we need to reduce the amount of current by $I_S - I_0$. This may be accomplished if the amplification factor is $-\frac{R}{L}$, and the input voltage from the voltage supply is $\frac{I}{L} I_0$. In this case, the amplifier will respond by emitting a current of $I_0 - I_S$ as desired.