Basic Wilson model of cortical neurons. It is a single-compartment model. Ionotropic synapses (or test current sources) are connected at the terminals on the left. The model combines the Na\(^+\) voltage-gated channel and the leakage channel together in one element, modeled as a fictitious persistent Na\(^+\) channel. It adds a voltage-dependent Ca\(^{2+}\) channel, commonly called a “T” channel, and a Ca\(^{2+}\)-dependent K\(^+\) channel (the “H” channel) to the basic Hodgkin-Huxley channels. The batteries representing the Nernst potentials are all placed with the “+” terminal facing the cytoplasmic side of the membrane, and the numerical values for the various “E” terms above carry the sign of the Nernst potential. Thus E\(_K\) would be a negative number in this circuit model, while E\(_{Na}\) would be a positive number. This is indeed the preferred circuit convention for numerical modeling because it simplifies the computer code used.
Response of a Wilson RS-type neuron model to excitatory inputs. The arrival time and number of simultaneous excitatory inputs is given in the figure. The IC time constant was 2 msec. Note the integrator-like response of the membrane potential for $t = 10$ and $t = 50$ msec. Note also that the response is not linear. At $t = 90$ msec the arrival of a volley of 60 synaptic inputs opens enough voltage-gated Na$^+$ channels to stimulate an action potential. However, a volley of 80 inputs at $t = 130$ is not sufficient to trigger another AP. This is because the first AP has opened all the K$^+$ channels and these have not all deactivated by $t = 130$. (Note the slight hyperpolarization of the membrane potential around $t = 100$ msec and again at around $t = 180$ msec). Their inhibitory effect outweighs the excitatory synaptic input and no AP is produced. This phenomenon is called the relative refractory time of the neuron. Note that the membrane voltage’s time constant is smaller (faster) at $t = 130$ compared to $t = 10$ and $t = 50$. This is because of the increased K$^+$ channel conductance. At $t = 170$ the combination of more input APs and decreased K$^+$ conductance results in the generation of a second action potential.
RS-type firing under laboratory test conditions stimulated by injection of an excitatory current from $t = 10$ to $t = 190$ msec.
Class-1 IB-type firing pattern in response to constant current injection from $t = 10$ to $t = 190$ msec.
RS-type response to constant current injection from $t = 10$ to $t = 120$ msec. This response is characterized by lack of accommodation in the firing rate and by high-frequency spiking. There are three subclasses of RS response. The firing pattern illustrated here belongs to the c-NAC subclass.
CS-type firing response to a constant-stimulus injected current.