Allen Cell Types Features Glossary

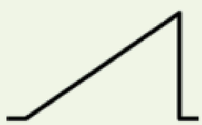
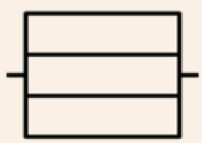
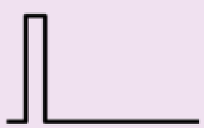
This glossary provides a short definition of the features available via the `get_ephys_features()` method.

Notes

- Some of these features were obtained from single spikes or subthreshold responses, others are obtained from spike trains.
- More detailed information can be found in the Allen Brain Atlas whitepaper.
- If you're interested in computing additional features, you can do so with the EphysSweepFeatureExtractor.

Stimulus Types

Spike train features were recorded in response to three different types of current injections:

Ramp		*Description*: Current injection of increasing intensity at a rate much slower than the time constant of the neuron. *Details*: Ramp of 25 pA per 1 second, terminated after a series of action potentials are acquired.
Long Square		*Description*: Square pulse of a duration to allow the neuron to come to steady-state. *Details*: 1 s current injections from -110 pA (or -190 for some Pvalb neurons) to rheobase + 160 pA, in 20 pA increments. For some human neurons with low IR, steps were from -220 pA in 40 pA increments.
Short Square		*Description*: Square pulse brief enough to elicit a single action potential. *Details*: 3 ms current injections used to find the action potential threshold within 10 pA.

Recorded Features

`adaptation`: The rate at which firing speeds up or slows down during a stimulus, defined as:

$$\frac{1}{N-1}\sum_{n=1}^{N-1}\frac{ISI_{n+1}-ISI_n}{ISI_{n+1}+ISI_n}$$

where N is the number of interspike intervals (ISIs) in the sweep.

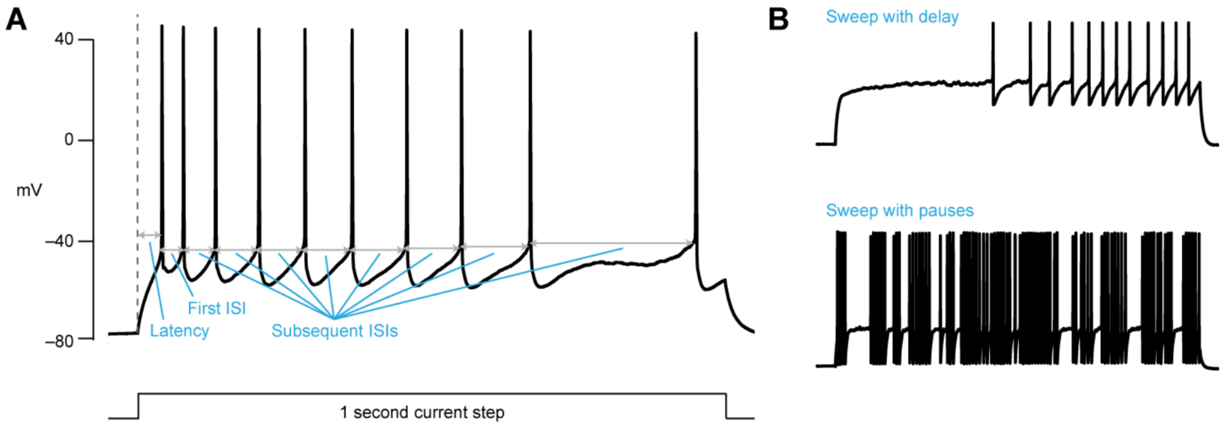


Figure 5. Illustration of action potential train features.
A. Sweep illustration of features such as latency, first ISI, and other ISIs. More complex features are calculated based on combinations of these features. **B.** Examples of sweeps containing a delay (*top*) and pauses *(bottom*).

`avg_isi`: the mean value of all interspike intervals in a sweep

`electrode_0_pa`: pipette offset

`f_i_curve_slope`: slope of the curve between firing rate (f) and current injected (i). See Figure 6C below.

`fast_trough`: timestamp (`_t`) or voltage (`_v`) of the trough within in the interval 5 ms after the peak in response to a short square stimulus (`_short_square`), a long square (`_long_square`), a ramp (`_ramp`).

> Note: The term "*trough*" has been used here to describe features of the action potential after the action potential rather than the term "after-hyperpolarization" since in many cases the membrane potential did not hyperpolarize below the baseline membrane potential.

`has_burst`: boolean; spike train was defined as having a burst if its first two ISIs were both less than or equal to 5 ms.

`has_delay`: boolean; a spike train was defined as having a delayed start to firing if the latency was greater than the average ISI (Figure 5B)

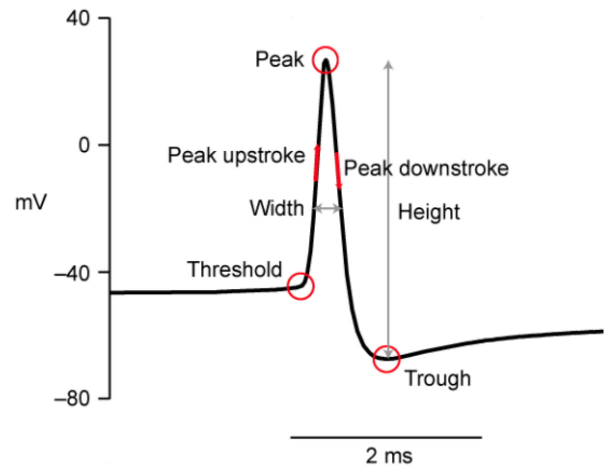
`has_pause`: boolean; spike train was defined as having a pause if any ISI was more than 3 times the duration of the ISIs immediately before and after it (i.e., at least two spikes on average were "skipped"), see Figure 5B.

`id`: internal id for each cell (you could use it, for instance, to cross-reference to morphology data or to the web viewer for the cell types database)

`input_resistance_mohm`: input resistance of the cell in mOhms

`latency`: time for the stimulus onset to the threshold of the first spike

peak: timestamp (_t) or voltage (_v) of the maximum value of the membrane potential during the action potential (i.e. between the action potential's threshold and the time of the next action potential, or end of the response) in response to a (_short_square), a long square (_long_square), a ramp (_ramp) stimulus



rheobase_sweep_id: sweep ID corresponding to the rheobase current

rheobase_sweep_number: sweep number corresponding to the rheobase current

ri: input resistance

sag: measurement of sag, or the return to steady state divided by the peak deflection (see Figure 6B below). From the white paper:

> "The response to a negative-going current step in which the minimum membrane potential was closest to -100 mV was selected for analysis of the membrane "sag" that can occur due to hyperpolarization-activated cationic currents (**Figure 6B**). The difference in the resting potential between the minimum value and the steady- state value was divided by the peak deflection during the stimulus to calculate a sag fraction that varied from 0 (no sag) to 1 (complete return back to the resting potential). In some cells, it was difficult to hyperpolarize the cells to -100 mV due to their low input resistances, so in all cases the membrane potential at which the sag was evaluated was also reported."

seal_gohm: measurement of the gigaohm seal obtained in whole-cell patch clamp configuration

slow_trough: timestamp (_t) or voltage (_v) of the membrane potential in the interval between the peak and the time of the next action potential in response to a short square stimulus (_short_square), a long square (_long_square), a ramp (_ramp). If the time between the peak and the next action potential was less than 5 ms, this value was identical to the fast trough.

> Note: The term "*trough*" has been used here to describe features of the action potential after the action potential rather than the term "after-hyperpolarization" since in many cases the membrane potential did not hyperpolarize below the baseline membrane potential.

specimen_id: cell ID

tau: membrane time constant, in ms

threshold: timestamp (_t) or voltage (_v) of the threshold current necessary using a short square stimulus (_short_square), a long square (_long_square), a ramp (_ramp)

thumbnail_sweep_id: sweep ID chosen for a thumbnail image

upstroke_downstroke_ratio: the ratio between the absolute values of the action potential peak upstroke and the action potential peak downstroke.during a short square (`_short_square`), a long square (`_long_square`), a ramp (`_ramp`) stimulus

vm_for_sag: the peak deflection at which sag is measured (targeted at -100 mV, but not always exact)

vrest: resting membrane potential, in mV

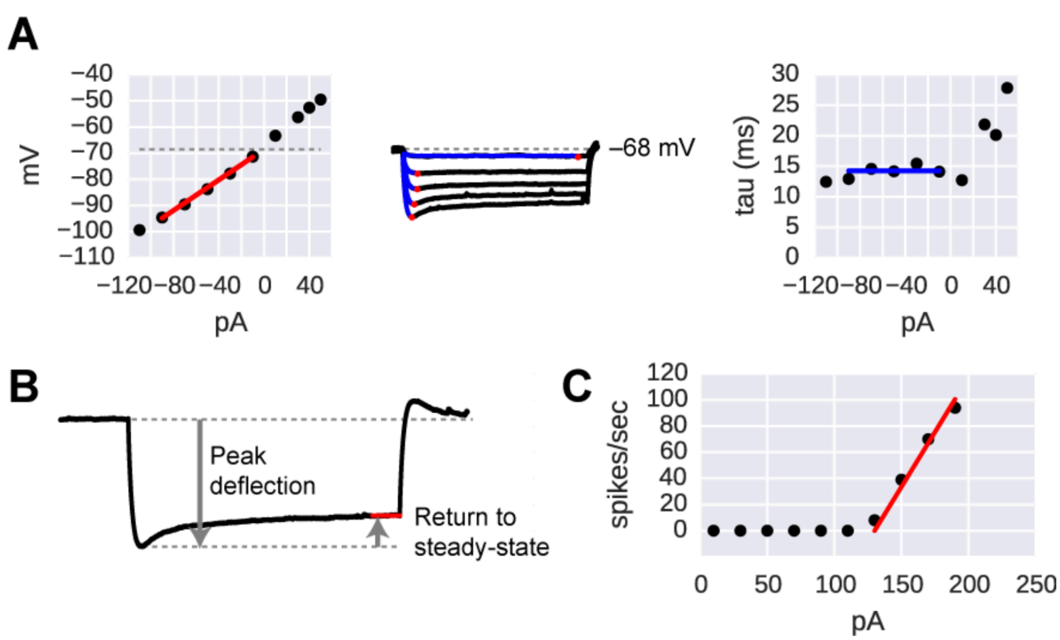


Figure 6. Illustration of cell-wide features calculated across multiple sweeps.
A. Illustration of features calculated from a series of subthreshold steps. The minimum values of the voltage are identified (*middle, red dots*), plotted versus the injected current, and fit with a line (*left, red line*) to estimate the input resistance. The baseline potential is shown by the *dotted gray line* on the leftmost plot. Single exponential fits (*blue lines, middle*) are made to these steps, and the time constants are plotted versus the injected current (*right*) and averaged (*right, blue line*). The voltage scale in the middle is the same as the right, and stimulus steps were one second long. **B.** Example of calculation of the sag, which equaled the return to steady state divided by the peak deflection. **C.** Illustration of an "f-I curve" along with the linear fit to the suprathreshold component that yielded the f-I curve slope feature. Data in panels **A** and **B** are from the same cell; data in **C** are from a different cell.

Table of all features with related neuroscience principles

Variable	Description	Related neuroscience principles
`adaptation`	The rate at which firing speeds up or slows down during a stimulus, defined as: $\frac{1}{N-1}\sum_{n=1}^{N-1}\frac{ISI_{n+1}-ISI_n}{ISI_{n+1}+ISI_n}$ where N is the number of interspike intervals (ISIs) in the sweep	Learning and memory, integration of inputs in single cells, sensory adaptation, habituation vs. adaptation, information transmission
`avg_isi`	The mean value of all interspike intervals in a sweep	Mechanisms of an action potential, integration of inputs in single cells, information transmission
`fast_trough`	timestamp (_t) or voltage (_v) of the trough within in the interval 5 ms after the peak in response to a short square stimulus (_short_square), a long square (_long_square), a ramp (_ramp).	Mechanisms of an action potential, the role of ion channels in the shape of an action potential
`f_i_curve_slope`	slope of the curve between firing rate (f) and current injected; see the Allen Institute Whitepaper for details	The relationship between input and firing rate
`input_resistance_mohm`	input resistance of the cell, in mega ohms	Passive membrane properties, Ohm's law
`latency`	time for the stimulus onset to the threshold of the first spike	Integration of inputs in single cells, sensory integration
`peak`	timestamp (_t) or voltage (_v) of the maximum value of the membrane potential during the action potential (i.e., between the action potential's threshold and the time of the next action potential, or end of the response) in response to a (_short_square), a long square (_long_square), a ramp (_ramp) stimulus	Mechanisms of an action potential, the role of ion channels in the shape of an action potential
`sag`	measurement of sag, or the return to steady state divided by the peak deflection	I_h currents, subthreshold properties
`slow_trough`	timestamp (_t) or voltage (_v) of the membrane potential in the interval between the peak and the time of the next action potential in response to a short square stimulus (_short_square), a long square (_long_square), a ramp (_ramp)	Mechanisms of an action potential, the role of ion channels in the shape of an action potential
`tau`	membrane time constant, in ms	Passive membrane properties, Ohm's law, membrane time constants, capacitance
`upstroke_downstroke_ratio`	the ratio between the absolute values of the action potential peak upstroke and the action potential peak downstroke.during a short square (_short_square), a long square (_long_square), a ramp (_ramp) stimulus	Mechanisms of an action potential, the role of ion channels in the shape of an action potential
`vrest`	resting membrane potential, in mV	Mechanisms of establishing and maintaining a resting membrane potential, role of ions and channels in the resting membrane potential