Extract Intrinsic Currents from Raw ABF files of Voltage Steps

In [1]:
```
import pyabf
import os
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
from IPython.display import display, HTML
from sklearn.metrics import auc

```

Read in the data

In [2]:
```
dir_in = r'\Projects\All Olive\Intrinsic\ABF\'
#dir_in = dir_in.replace (r'\', r'\\')
file_in = '2019_08_08_0018.abf'
dir_out = dir_in + '\\Analyzed'

os.chdir (dir_in)
abf = pyabf.ABF(file_in)
```

Function Definitions

Set up the data frame

In [3]:
```
columns = {'filename':[], 'vstep':[], 'baseline':[],'h_peak':[],'ss_peak':[],'ahp_peak':[],
           'ca_peak':[],'i_h':[],'i_ahp':[],'i_ca':[],'i_input':[],'r_input':[]}

channels = [0,2]
sweep_list = abf.sweepList # Get all sweeps in the file
step_list = list([-55, -45, -35, -25, -15, -5, 5, 15, 25, 35, 45, 55])


```

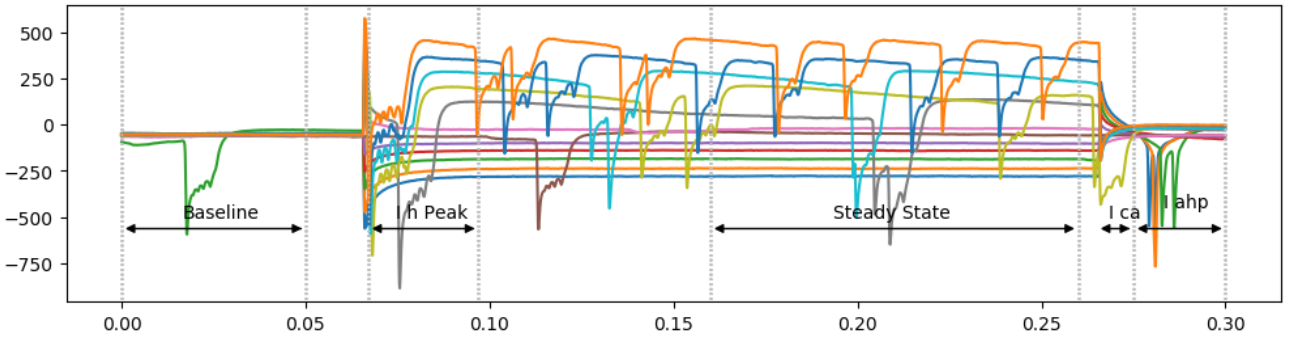
Analyze the raw traces for relevant peaks for Ch1

In [4]:

```
channel = 0
x1 = np.nan
x2 = np.nan
y1 = np.nan
y2 = np.nan

baseline_start = 0 * abf.dataPointsPerMs
baseline_end = 50 * abf.dataPointsPerMs
h_start = 67  * abf.dataPointsPerMs
h_end = 97  * abf.dataPointsPerMs
ss_start = 160 * abf.dataPointsPerMs
ss_end = 260  * abf.dataPointsPerMs
ahp_start = 275 * abf.dataPointsPerMs
ahp_end = 300  * abf.dataPointsPerMs
ca_start = 265 * abf.dataPointsPerMs
ca_end = 275 * abf.dataPointsPerMs

df = pd.DataFrame.from_dict (columns)
file_out = file_in.replace('.abf','') + '_Ch_' + str(channel) + '.csv'
i = 0
fig, ax = plt.subplots(1,1, figsize=(12, 3), dpi = 100)
for sweep in sweep_list:

    filename = file_in
    vstep = step_list[i]
    abf.setSweep (sweepNumber = sweep, channel = channel)
    x = abf.sweepX[baseline_start:ahp_end]
    y = abf.sweepY[baseline_start:ahp_end]
    x_min = min(x)
    x_max = max(x)
    y_min = min (y)
    y_max = max(y)


    sf = abf.dataPointsPerMs  *1000 # scale factor for referencing time on the plotted data (points/sec)
    baseline = np.average (abf.sweepY [baseline_start: baseline_end])
    h_peak = np.max (abf.sweepY [h_start: h_end])
    ss_peak = np.average (abf.sweepY [ss_start: ss_end])
    ahp_peak = np.max (abf.sweepY [ahp_start: ahp_end])
    ca_peak = np.min (abf.sweepY [ca_start: ca_end])

    i_ss = ss_peak - baseline
    i_h = h_peak - ss_peak
    i_ahp = ahp_peak - baseline
    i_ca = ca_peak - baseline
    i_input = ss_peak - baseline
    r_input = vstep/i_input * 1000
    df = df.append ([{'filename':filename, 'vstep':vstep, 'baseline':baseline, 'h_peak':h_peak,
                    'ss_peak':ss_peak, 'ahp_peak':ahp_peak, 'ca_peak':ca_peak,
                    'i_ss':i_ss,'i_h':i_h,'i_ahp':i_ahp,
                    'i_ca':i_ca, 'i_input':i_input, 'r_input': r_input}], sort = False)
    df = df[['filename', 'vstep', 'baseline', 'i_ss','i_h','i_ahp','i_ca', 'r_input',
        'h_peak', 'ss_peak', 'ahp_peak',  'ca_peak', 'i_input']]

    ax.plot (x, y, linestyle = 'solid')

    ax.axvline(baseline_start/sf, y_min, y_max, color = 'silver', lw = 1, linestyle = ':')
    ax.axvline(baseline_end/sf  , y_min, y_max , color = 'silver', lw = 1, linestyle = ':')
    ax.axvline(h_start/sf, y_min, y_max , color = 'silver', lw = 1, linestyle = ':')
    ax.axvline(h_end/sf, y_min, y_max, color = 'silver', lw = 1, linestyle = ':')
    ax.axvline(ahp_start/sf, y_min, y_max , color = 'silver', lw = 1, linestyle = ':')
    ax.axvline(ahp_end/sf, y_min, y_max , color = 'silver', lw = 1, linestyle = ':')
    ax.axvline(ss_start/sf,y_min, y_max , color = 'silver', lw = 1, linestyle = ':')
    ax.axvline(ss_end/sf, y_min, y_max , color = 'silver', lw = 1, linestyle = ':')

    if i == 0:
        ax.annotate('Baseline', xy=((baseline_end/sf - baseline_start/sf)/3, y_min - y_min *0.1), color = 'black')
        ax.annotate('', xy=(baseline_start/sf, y_min), xytext = (baseline_end/sf, y_min),
                    arrowprops=dict(arrowstyle="<|-|>", connectionstyle = "bar, fraction = 0", color = 'black'))
        ax.annotate('I h Peak', xy=(h_start/sf + (h_end/sf - h_start/sf)/4, y_min - y_min *0.1))
        ax.annotate('', xy=(h_start/sf, y_min), xytext = (h_end/sf, y_min),
                    arrowprops=dict(arrowstyle="<|-|>", connectionstyle = "bar, fraction = 0", color = 'black'))
        ax.annotate('Steady State', xy=(ss_start/sf + (ss_end/sf - ss_start/sf)/3, y_min - y_min *0.1))
        ax.annotate('', xy=(ss_start/sf, y_min), xytext = (ss_end/sf, y_min),
                    arrowprops=dict(arrowstyle="<|-|>", connectionstyle = "bar, fraction = 0", color = 'black'))
        ax.annotate('I ahp', xy=(ahp_start/sf + (ahp_end/sf - ahp_start/sf)/3, y_min - y_min *0.2))
        ax.annotate('I ca', xy=(ca_start/sf + (ca_end/sf - ca_start/sf)/3, y_min - y_min *0.1))
        ax.annotate('', xy=(ahp_start/sf, y_min), xytext = (ahp_end/sf, y_min),
                    arrowprops=dict(arrowstyle="<|-|>", connectionstyle = "bar, fraction = 0", color = 'black'))
        ax.annotate('', xy=(ca_start/sf, y_min), xytext = (ca_end/sf, y_min),
                    arrowprops=dict(arrowstyle="<|-|>", connectionstyle = "bar, fraction = 0", color = 'black'))
```

```
82
83
84      i = i + 1
85
86  display(HTML(df.to_html()))
87
88  try:
89      os.stat(dir_out)
90  except:
91      os.makedirs(dir_out)
92
93  # Write data to file
94  os.chdir(dir_out)
95  df.to_csv(file_out, index = False)
96
97
```

	filename	vstep	baseline	i_ss	i_h	i_ahp	i_ca	r_input	h_peak	ss_peak	ahp_peak	ca
0	2019_08_08_0018.abf	-55.0	-47.492676	-231.740143	-2.139252	37.727051	-232.658691	237.334798	-281.372070	-279.232819	-9.765625	-280.1
0	2019_08_08_0018.abf	-45.0	-55.115971	-183.106689	-1.645508	36.195072	-182.921143	245.758362	-239.868164	-238.222656	-18.920898	-238.0
0	2019_08_08_0018.abf	-35.0	-115.291748	-71.188354	0.322876	101.253662	-78.189697	491.653449	-186.157227	-186.480103	-14.038086	-193.4
0	2019_08_08_0018.abf	-25.0	-50.209961	-90.114136	-0.667114	11.147461	-90.781250	277.425953	-140.991211	-140.324097	-39.062500	-140.9
0	2019_08_08_0018.abf	-15.0	-56.231686	-44.243778	-0.842896	4.962154	-48.138432	339.030720	-101.318359	-100.475464	-51.269531	-104.3
0	2019_08_08_0018.abf	-5.0	-62.366947	12.844852	-13.954468	5.604252	3.162846	-389.260992	-63.476562	-49.522095	-56.762695	-59.2
0	2019_08_08_0018.abf	5.0	-63.043209	41.129147	46.328125	6.280514	-67.572021	121.568290	24.414062	-21.914062	-56.762695	-130.6
0	2019_08_08_0018.abf	15.0	-59.052734	89.548950	94.015503	36.469727	-45.927734	167.506151	124.511719	30.496214	-22.583008	-104.9
0	2019_08_08_0018.abf	25.0	-56.580814	197.955917	63.092667	50.477299	-376.158447	126.290744	204.467773	141.375107	-6.103516	-432.7
0	2019_08_08_0018.abf	35.0	-49.968262	267.472534	68.750595	32.268066	-145.344238	130.854557	286.254883	217.504288	-17.700195	-195.3
0	2019_08_08_0018.abf	45.0	-52.509766	341.010742	77.709961	48.847656	-126.323242	131.960652	366.210938	288.500977	-3.662109	-178.8
0	2019_08_08_0018.abf	55.0	-53.117676	433.768921	74.671021	51.896973	-139.753418	126.795622	455.322266	380.651245	-1.220703	-192.8

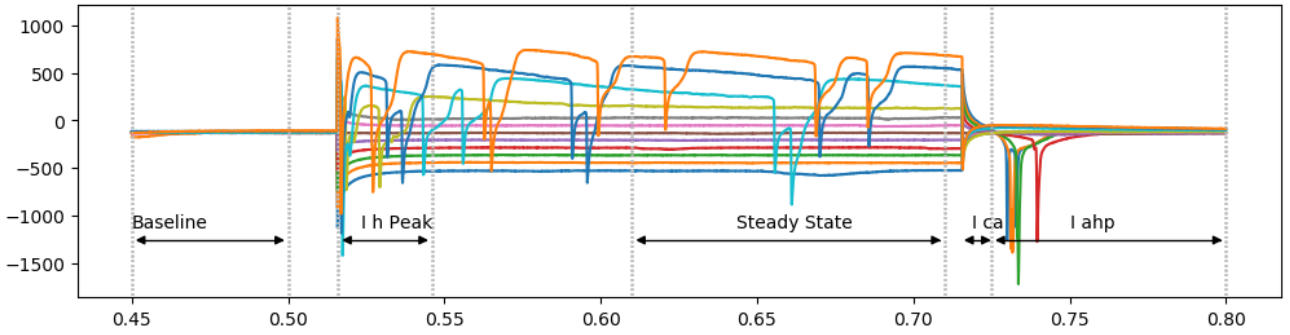


In [5]:

```
channel = 2
x1 = np.nan
x2 = np.nan
y1 = np.nan
y2 = np.nan

baseline_start = 450  * abf.dataPointsPerMs
baseline_end = 500  * abf.dataPointsPerMs
h_start = 516 * abf.dataPointsPerMs
h_end =  546 * abf.dataPointsPerMs
ss_start =  610 * abf.dataPointsPerMs
ss_end = 710  * abf.dataPointsPerMs
ahp_start =  725 * abf.dataPointsPerMs
ahp_end = 800  * abf.dataPointsPerMs
ca_start = 715 * abf.dataPointsPerMs
ca_end = 726* abf.dataPointsPerMs

df = pd.DataFrame.from_dict (columns)
file_out = file_in.replace('.abf','') + '_Ch_' + str(channel) + '.csv'
i = 0
fig, ax = plt.subplots(1,1, figsize=(12, 3), dpi = 100)
for sweep in sweep_list:
    filename = file_in
    vstep = step_list[i]
    abf.setSweep (sweepNumber = sweep, channel = channel)
    x = abf.sweepX[baseline_start:ahp_end]
    y = abf.sweepY[baseline_start:ahp_end]
    x_min = min(x)
    x_max = max(x)
    y_min = min (y)
    y_max = max(y)
    sf = abf.dataPointsPerMs  *1000 # scale factor for referencing time on the plotted data (points/sec)
    baseline = np.average (abf.sweepY [baseline_start: baseline_end])
    h_peak = np.max (abf.sweepY [h_start: h_end])
    ss_peak = np.average (abf.sweepY [ss_start: ss_end])
    ahp_peak = np.max (abf.sweepY [ahp_start: ahp_end])
    ca_peak = np.min (abf.sweepY [ca_start: ca_end])

    i_ss = ss_peak - baseline
    i_h = h_peak - ss_peak
    i_ahp = ahp_peak - baseline
    i_ca = ca_peak - baseline
    i_input = ss_peak - baseline
    r_input = vstep/i_input * 1000
    df = df.append ([{'filename':filename, 'vstep':vstep, 'baseline':baseline, 'h_peak':h_peak,
                      'ss_peak':ss_peak, 'ahp_peak':ahp_peak, 'ca_peak':ca_peak, 'i_ss':i_ss,
                      'i_h':i_h,'i_ahp':i_ahp, 'i_ca':i_ca, 'i_input':i_input, 'r_input': r_input}], sort = False)
    df = df[['filename', 'vstep', 'baseline', 'i_ss','i_h','i_ahp','i_ca', 'r_input',
             'h_peak', 'ss_peak', 'ahp_peak','ca_peak', 'i_input']]


    ax.plot (x, y, linestyle = 'solid')

    ax.axvline(baseline_start/sf, y_min, y_max, color = 'silver', lw = 1, linestyle = ':')
    ax.axvline(baseline_end/sf  , y_min, y_max , color = 'silver', lw = 1, linestyle = ':')
    ax.axvline(h_start/sf, y_min, y_max , color = 'silver', lw = 1, linestyle = ':')
    ax.axvline(h_end/sf, y_min, y_max, color = 'silver', lw = 1, linestyle = ':')
    ax.axvline(ahp_start/sf, y_min, y_max , color = 'silver', lw = 1, linestyle = ':')
    ax.axvline(ahp_end/sf, y_min, y_max , color = 'silver', lw = 1, linestyle = ':')
    ax.axvline(ss_start/sf,y_min, y_max , color = 'silver', lw = 1, linestyle = ':')
    ax.axvline(ss_end/sf, y_min, y_max , color = 'silver', lw = 1, linestyle = ':')

    if i == 0:
        ax.annotate('Baseline', xy=(baseline_start/sf, y_min - y_min *0.1), color = 'black')
        ax.annotate('', xy=(baseline_start/sf, y_min), xytext = (baseline_end/sf, y_min),
                    arrowprops=dict(arrowstyle="<|-|>", connectionstyle = "bar, fraction = 0", color = 'black'))
        ax.annotate('I h Peak', xy=(h_start/sf + (h_end/sf - h_start/sf)/4, y_min - y_min *0.1))
        ax.annotate('', xy=(h_start/sf, y_min), xytext = (h_end/sf, y_min),
                    arrowprops=dict(arrowstyle="<|-|>", connectionstyle = "bar, fraction = 0", color = 'black'))
        ax.annotate('Steady State', xy=(ss_start/sf + (ss_end/sf - ss_start/sf)/3, y_min - y_min *0.1))
        ax.annotate('', xy=(ss_start/sf, y_min), xytext = (ss_end/sf, y_min),
                    arrowprops=dict(arrowstyle="<|-|>", connectionstyle = "bar, fraction = 0", color = 'black'))
        ax.annotate('I ahp', xy=(ahp_start/sf + (ahp_end/sf - ahp_start/sf)/3, y_min - y_min *0.1))
        ax.annotate('I ca', xy=(ca_start/sf + (ca_end/sf - ca_start/sf)/3, y_min - y_min *0.1))
        ax.annotate('', xy=(ahp_start/sf, y_min), xytext = (ahp_end/sf, y_min),
                    arrowprops=dict(arrowstyle="<|-|>", connectionstyle = "bar, fraction = 0", color = 'black'))
        ax.annotate('', xy=(ca_start/sf, y_min), xytext = (ca_end/sf, y_min),
                    arrowprops=dict(arrowstyle="<|-|>", connectionstyle = "bar, fraction = 0", color = 'black'))


    i = i + 1
```

```
82
83 display(HTML(df.to_html()))
84
85 try:
86     os.stat(dir_out)
87 except:
88     os.makedirs(dir_out)
89
90 # Write data to file
91 os.chdir(dir_out)
92 df.to_csv(file_out, index = False)
93
94
95
```

	filename	vstep	baseline	i_ss	i_h	i_ahp	i_ca	r_input	h_peak	ss_peak	ahp_peak	c
0	2019_08_08_0018.abf	-55.0	-115.330811	-424.971924	9.296875	41.478271	-412.012939	129.420314	-531.005859	-540.302734	-73.852539	-527.
0	2019_08_08_0018.abf	-45.0	-132.708755	-312.553101	3.367310	51.531998	-314.068604	143.975535	-441.894531	-445.261841	-81.176758	-446.
0	2019_08_08_0018.abf	-35.0	-124.503174	-240.390625	-1.317139	31.119385	-241.097412	145.596360	-366.210938	-364.893799	-93.383789	-365.
0	2019_08_08_0018.abf	-25.0	-128.389893	-160.430908	1.345215	6.319580	-167.630615	155.830321	-287.475586	-288.820801	-122.070312	-296.
0	2019_08_08_0018.abf	-15.0	-129.107666	-77.280884	2.531128	8.258057	-77.191162	194.097159	-203.857422	-206.388550	-120.849609	-206.
0	2019_08_08_0018.abf	-5.0	-131.198715	-2.096573	3.290405	3.635239	-3.688980	2384.844361	-130.004883	-133.295288	-127.563477	-134.
0	2019_08_08_0018.abf	5.0	-129.313965	74.451904	95.755615	7.243652	-111.164551	67.157449	40.893555	-54.862064	-122.070312	-240.
0	2019_08_08_0018.abf	15.0	-123.459480	148.177490	184.022217	6.882332	-217.116699	101.229950	208.740234	24.718018	-116.577148	-340.
0	2019_08_08_0018.abf	25.0	-126.859131	261.363525	251.237778	13.944092	-324.190674	95.652215	385.742188	134.504410	-112.915039	-451.
0	2019_08_08_0018.abf	35.0	-126.121826	388.782959	294.589844	50.438232	-288.917236	90.024522	557.250977	262.661133	-75.683594	-415.
0	2019_08_08_0018.abf	45.0	-118.348389	561.715088	296.989716	63.416748	-322.325439	80.111788	740.356445	443.366730	-54.931641	-440.
0	2019_08_08_0018.abf	55.0	-114.869385	706.503906	331.827393	67.872314	-399.046631	77.848119	923.461914	591.634521	-46.997070	-513.



In [ ]:
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