Lab4_Azfar

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[ ]:
```
# For use with VScope v1.4r1
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```

[ ]:
```
import serial
import serial.tools.list_ports

import threading
import time

import plotly
from ipywidgets import␣
 ↪interactive_output,fixed,Button,ToggleButtons,SelectionSlider,IntSlider,FloatSlider,HTML,HB
from IPython.display import display

import numpy as np

VID=61525
PID=38912
BAUDRATE=115200
BUFFERSIZE=1000
```

[ ]:
```
# VScopeBoard class

class VScopeBoard:

    def __init__(self,vid=VID,pid=PID,baudrate=BAUDRATE):
        ports=serial.tools.list_ports.comports()
        for p in ports:
            if p.vid==vid and p.pid==pid:
                self.device=serial.Serial(p.device,baudrate=baudrate)
        if not hasattr(self,'device'):
            raise Exception('No controller unit detected')
        self.device.close()

       ␣
 ↪###########################################################################
```

```
        # Enter your calibration data below
        # W1/W2 DC bias
        self.w1bias=0.141 # W1 DC bias reading in V; set it to 0 before␣
↪calibrating
        self.w2bias=0.101 # W2 DC bias reading in V; set it to 0 before␣
↪calibrating
      ␣
↪############################################################################
        # CH1/CH2: gain and offset look-up table
        # 'dc' calibrate at each vscale
        # 'dc'=-bias/'amp'+'dc'
        self.p1={0.02 :{'gain':224,'amp':0.0950,'dc':2,'dco':130,'dco_c2':
↪171,'aco_c2':-0.005},
                 0.05 :{'gain':208,'amp':0.1500,'dc':1.91,'dco':130,'dco_c2':
↪168,'aco_c2':-0.000},
                 0.1  :{'gain':160,'amp':0.3900,'dc':1.83,'dco':130,'dco_c2':
↪159,'aco_c2':-0.020},
                 0.2  :{'gain':138,'amp':0.5500,'dc':1.81,'dco':130,'dco_c2':
↪157,'aco_c2':-0.050},
                 0.5  :{'gain':220,'amp':2.1700,'dc':2.06,'dco':130,'dco_c2':
↪130,'aco_c2':-0.000},
                 1    :{'gain':212,'amp':2.8500,'dc':2.0,'dco':130,'dco_c2':
↪130,'aco_c2':-0.000},
                 2    :{'gain':160,'amp':7.9000,'dc':1.85,'dco':130,'dco_c2':
↪130,'aco_c2':-0.000},
                 5    :{'gain':106,'amp':19.100,'dc':1.81,'dco':130,'dco_c2':
↪130,'aco_c2':-0.000}}
        self.p2={0.02 :{'gain':224,'amp':0.0950,'dc':2.03,'dco':130,'dco_c2':
↪171,'aco_c2':-0.025},
                 0.05 :{'gain':208,'amp':0.1500,'dc':1.93,'dco':130,'dco_c2':
↪167,'aco_c2':-0.020},
                 0.1  :{'gain':160,'amp':0.3900,'dc':1.84,'dco':130,'dco_c2':
↪159,'aco_c2':-0.040},
                 0.2  :{'gain':138,'amp':0.5500,'dc':1.82,'dco':130,'dco_c2':
↪158,'aco_c2':-0.070},
                 0.5  :{'gain':220,'amp':2.1700,'dc':2.08,'dco':130,'dco_c2':
↪130,'aco_c2':-0.000},
                 1    :{'gain':212,'amp':2.8500,'dc':2.02,'dco':130,'dco_c2':
↪130,'aco_c2':-0.000},
                 2    :{'gain':160,'amp':7.9000,'dc':1.86,'dco':130,'dco_c2':
↪130,'aco_c2':-0.000},
                 5    :{'gain':106,'amp':18.800,'dc':1.81,'dco':130,'dco_c2':
↪130,'aco_c2':-0.000}}
      ␣
↪############################################################################
```

```
    # Set DC power supply voltage VDCP and VDCN
    def set_vdc(self,voltage):
        cmd='dz'+str(int(voltage*100)).zfill(4)+'\r'
        self.device.open()
        self.device.reset_output_buffer()
        self.device.write(bytes(cmd,'utf-8'))
        self.device.close()

    # Generate waveforms on W1 and W2
    def generate_wave(self,channel,shape,amp,freq,offset):
        if channel==1:
            offset-=self.w1bias
            cmd='s1'
        else:
            offset-=self.w2bias
            cmd='s2'
        ns=64
        if shape=='Triangular':
            cmd+=str(10).zfill(2)
        elif shape=='Sawtooth':
            cmd+=str(11).zfill(2)
        else:
            cmd+=str(0).zfill(2)
        cmd+=str(ns).zfill(3)+str(freq).zfill(7)+str(int(amp*100)).
↪zfill(4)+str(int(offset*100)).zfill(4)+'\r'
        self.device.open()
        self.device.reset_output_buffer()
        self.device.write(bytes(cmd,'utf-8'))
        self.device.close()

    # Capture oscilloscope traces on CH1 and CH2
    def capture_oscscope(self,tbase,vscale1,coupling1,vscale2,coupling2):
        if tbase>1100:
            fs=50000
        elif tbase>510:
            fs=100000
        else:
            fs=200000 # maximum sampling rate=210 kHz
        if coupling1=='DC':
            c1=0 if vscale1<0.4 else 1
        else:
            c1=2 if coupling1=='AC' else 3
        if coupling2=='DC':
            c2=0 if vscale2<0.4 else 1
        else:
            c2=2 if coupling2=='AC' else 3
```

```
        if c1==2:
            dco1=self.p1[vscale1]['dco_c2']
            aco1=self.p1[vscale1]['aco_c2']
        else:
            dco1=self.p1[vscale1]['dco']
            aco1=0
        if c2==2:
            dco2=self.p2[vscale1]['dco_c2']
            aco2=self.p2[vscale1]['aco_c2']
        else:
            dco2=self.p2[vscale1]['dco']
            aco2=0
        cmd='m1'+str(fs).zfill(6)+str(c1)+str(self.p1[vscale1]['gain']).
↪zfill(3)+str(dco1).zfill(3)+str(c2)+str(self.p2[vscale2]['gain']).
↪zfill(3)+str(dco2).zfill(3)+'\r'
        bytedata=bytearray(BUFFERSIZE*4)
        self.device.open()
        self.device.reset_output_buffer()
        self.device.reset_input_buffer()
        self.device.write(bytes(cmd,'utf-8'))
        self.device.readline()
        self.device.readinto(bytedata)
        self.device.close()
        data=np.frombuffer(bytedata,dtype='uint16').reshape((2,BUFFERSIZE))
        raw1=aco1+self.p1[vscale1]['amp']*(self.p1[vscale1]['dc']-1.5*data[0,:]/
↪1700)
        raw2=aco2+self.p2[vscale2]['amp']*(self.p2[vscale2]['dc']-1.5*data[1,:]/
↪1700)
        # Whittaer-Shannon interpolation for signal reconstruction on a finer␣
↪grid within the tbase*10 range
        n=2**9
        t=np.arange(n)*10*tbase*1e-6/n
        ch1=np.sum(np.multiply(raw1,np.transpose(np.sinc(t*fs-np.reshape(np.
↪arange(BUFFERSIZE),(BUFFERSIZE,1))))),axis=1)
        ch2=np.sum(np.multiply(raw2,np.transpose(np.sinc(t*fs-np.reshape(np.
↪arange(BUFFERSIZE),(BUFFERSIZE,1))))),axis=1)
        return t,ch1,ch2,raw1,raw2

    # Measure DC voltage on PC0 and PC1
    def measure_volt(self):
        cmd='m2\r'
        bytedata=bytearray(4)
        self.device.open()
        self.device.reset_output_buffer()
        self.device.reset_input_buffer()
        self.device.write(bytes(cmd,'utf-8'))
```

```
        self.device.readline()
        self.device.readinto(bytedata)
        self.device.close()
        data=np.frombuffer(bytedata,dtype='uint16')
        v1=3.3*data[0]/4095
        v2=3.3*data[1]/4095
        return v1,v2
```

[ ]:
```
# RepeatTimer class

class RepeatTimer:

    def __init__(self,interval,function,*args,**kwargs):
        self.interval=interval
        self.function=function
        self.args=args
        self.kwargs=kwargs
        self.is_running=False

    def _run(self):
        self.is_running=False
        try:
            self.function(*self.args,**self.kwargs)
        except:
            pass
        self.start()

    def start(self):
        if not self.is_running:
            self._timer=threading.Timer(self.interval,self._run)
            self._timer.start()
            self.is_running=True

    def stop(self):
        try:
            self._timer.cancel()
            self.is_running=False
        except:
            pass
```

[ ]:
```
vscope=VScopeBoard()
```

[ ]:
```
# # Calibrate CH1 and CH2 DC offset voltages
# # Work only in DC coupling mode
# # 1. Connect CH1 and CH2 pins to GND
# # 2. Execute all cells above
# # 3. Uncomment this cell and execute
```

```
# # 4. Note down the new 'dc' values and incorporate in the look-up table in␣
 ↪capture_oscscope()
# # 5. Comment back this cell once completed

# n_calibrate=10
# vdiv_list=[0.02,0.05,0.1,0.2,0.5,1,2,5]
# ch1_dc=list()
# ch2_dc=list()
# for vdiv in vdiv_list:
#     _,_,_,y1,y2=vscope.capture_oscscope(1000,vdiv,'DC',vdiv,'DC')
#     for i in range(n_calibrate-1):
#         time.sleep(0.5)
#         _,_,_,ch1,ch2=vscope.capture_oscscope(1000,vdiv,'DC',vdiv,'DC')
#         y1+=ch1
#         y2+=ch2
#     y1/=n_calibrate
#     y2/=n_calibrate
#     ch1_dc.append(vscope.p1[vdiv]['dc']-np.mean(y1)/vscope.p1[vdiv]['amp'])
#     ch2_dc.append(vscope.p2[vdiv]['dc']-np.mean(y2)/vscope.p2[vdiv]['amp'])
#     print('Completed calibrating '+str(vdiv).rjust(4)+' V/Div')
# for i, vdiv in enumerate(vdiv_list):
#     print('\'dc\' CH1 '+str(vdiv).rjust(4)+' V/Div: '+str(round(ch1_dc[i],2)))
# for i, vdiv in enumerate(vdiv_list):
#     print('\'dc\' CH2 '+str(vdiv).rjust(4)+' V/Div: '+str(round(ch2_dc[i],2)))
```

[ ]:

```
# DC voltage supply interface

vdc=FloatSlider(min=5.5,max=13.5,step=0.1,value=5.
 ↪5,continuous_update=False,readout_format='.1f',layout=Layout(width='500px'))
vdc_ui=HBox([Label(value='VDCP/VDCN␣
 ↪(±V)',layout=Layout(width='105px')),vdc],layout=Layout(justify_content='center',margin='5px
 ↪5px 5px 5px'))

ps_html='<h1 style=\'text-align:center;font-size:16px;background-color:
 ↪lightcoral\'>Dual DC Voltage Supply</h1>'
ps_title=HTML(value=ps_html,layout=Layout(width='820px'))
ps_ui=HBox([vdc_ui],layout=Layout(justify_content='space-around',width='820px',height='44px'))

interactive_output(vscope.set_vdc,{'voltage':vdc})
```

[ ]: Output()

[ ]:

```
# Waveform generator interface

shape1=ToggleButtons(options=['Sinusoidal','Triangular','Sawtooth'],value='Sinusoidal',style={
 ↪'80px'})
```

```
amp1=FloatSlider(min=0,max=5,step=0.01,value=0,readout_format='.
 ↪2f',continuous_update=False)
freq1=IntSlider(min=100,max=50000,step=100,value=1000,continuous_update=False)
offset1=FloatSlider(min=-6,max=6,step=0.01,value=0,readout_format='.
 ↪2f',continuous_update=False)

shape2=ToggleButtons(options=['Sinusoidal','Triangular','Sawtooth'],value='Sinusoidal',style={
 ↪'80px'})
amp2=FloatSlider(min=0,max=5,step=0.01,value=0,readout_format='.
 ↪2f',continuous_update=False)
freq2=IntSlider(min=100,max=50000,step=100,value=1000,continuous_update=False)
offset2=FloatSlider(min=-6,max=6,step=0.01,value=0,readout_format='.
 ↪2f',continuous_update=False)

shape1_ui=HBox([Label(value='Shape',layout=Layout(width='105px',display='flex',justify_content
amp1_ui=HBox([Label(value='Amplitude␣
 ↪(V)',layout=Layout(width='105px',display='flex',justify_content='flex-start')),amp1])
freq1_ui=HBox([Label(value='Frequency␣
 ↪(Hz)',layout=Layout(width='105px',display='flex',justify_content='flex-start')),freq1])
offset1_ui=HBox([Label(value='Offset␣
 ↪(V)',layout=Layout(width='105px',display='flex',justify_content='flex-start')),offset1])

shape2_ui=HBox([Label(value='Shape',layout=Layout(width='105px',display='flex',justify_content
amp2_ui=HBox([Label(value='Amplitude␣
 ↪(V)',layout=Layout(width='105px',display='flex',justify_content='flex-start')),amp2])
freq2_ui=HBox([Label(value='Frequency␣
 ↪(Hz)',layout=Layout(width='105px',display='flex',justify_content='flex-start')),freq2])
offset2_ui=HBox([Label(value='Offset␣
 ↪(V)',layout=Layout(width='105px',display='flex',justify_content='flex-start')),offset2])

wg1_ui=VBox([HTML('<h3 style=\'text-align:center;font-size:14px;margin-top:0px;
 ↪margin-bottom:0px\'>W1</
 ↪h3>'),shape1_ui,amp1_ui,freq1_ui,offset1_ui],layout=Layout(border='solid␣
 ↪2px',margin='5px 5px 5px 5px'))
wg2_ui=VBox([HTML('<h3 style=\'text-align:center;font-size:14px;margin-top:0px;
 ↪margin-bottom:0px\'>W2</
 ↪h3>'),shape2_ui,amp2_ui,freq2_ui,offset2_ui],layout=Layout(border='solid␣
 ↪2px',margin='5px 5px 5px 5px'))

wg_ui=HBox([wg1_ui,wg2_ui],layout=Layout(justify_content='space-around',width='820px',height='

wg_html='<h1 style=\'text-align:center;font-size:16px;background-color:
 ↪lightblue\'>Waveform Generator</h1>'
wg_title=HTML(value=wg_html,layout=Layout(width='820px'))
```

```
interactive_output(vscope.generate_wave,{'channel':fixed(1),'shape':
  ↪shape1,'amp':amp1,'freq':freq1,'offset':offset1})
interactive_output(vscope.generate_wave,{'channel':fixed(2),'shape':
  ↪shape2,'amp':amp2,'freq':freq2,'offset':offset2})
```

[ ]: Output()

[ ]:
```
# Oscilloscope interface

fig=plotly.graph_objs.FigureWidget()
fig.
  ↪update_layout(width=380,height=410,margin=dict(l=2,r=2,t=2,b=32),paper_bgcolor='black',show
fig.
  ↪update_layout(xaxis=dict(showticklabels=False,showgrid=True,gridwidth=1,gridcolor='black',z
fig.
  ↪update_layout(yaxis1=dict(tickmode='array',tickvals=[0],ticks='inside',tickwidth=2,tickcolo
  ↪colors.qualitative.
  ↪Plotly[0],showticklabels=False,showgrid=False,zeroline=False))
fig.
  ↪update_layout(yaxis2=dict(tickmode='array',tickvals=[0],ticks='inside',tickwidth=2,tickcolo
  ↪colors.qualitative.
  ↪Plotly[1],showticklabels=False,showgrid=False,zeroline=False,overlaying='y1'))
fig.
  ↪update_layout(yaxis3=dict(range=[-5,5],dtick=1,showticklabels=False,showgrid=True,gridwidth
fig.add_trace(plotly.graph_objs.Scatter(x=[],y=[],name='CH1',yaxis='y1'))
fig.add_trace(plotly.graph_objs.Scatter(x=[],y=[],name='CH2',yaxis='y2'))
fig.add_trace(plotly.graph_objs.Scatter(x=[],y=[],yaxis='y3'))
fig.add_annotation(dict(font=dict(family='Courier New,␣
  ↪monospace',color='white',size=10),x=0.5,y=-0.
  ↪04,showarrow=False,text='',textangle=0,xanchor='center',xref='paper',yref='paper'))
fig.add_annotation(dict(font=dict(family='Courier New,␣
  ↪monospace',color='white',size=10),x=0.5,y=-0.
  ↪08,showarrow=False,text='',textangle=0,xanchor='center',xref='paper',yref='paper'))
fig.add_annotation(dict(font=dict(family='Courier New, monospace',color=plotly.
  ↪colors.qualitative.Plotly[0],size=10),x=0.02,y=0.
  ↪99,showarrow=False,text='',textangle=0,xanchor='left',xref='paper',yref='paper'))
fig.add_annotation(dict(font=dict(family='Courier New, monospace',color=plotly.
  ↪colors.qualitative.Plotly[1],size=10),x=0.02,y=0.
  ↪95,showarrow=False,text='',textangle=0,xanchor='left',xref='paper',yref='paper'))
fig.add_annotation(dict(font=dict(family='Courier New,␣
  ↪monospace',color='black',size=10),x=0.98,y=0.
  ↪99,showarrow=False,text='',textangle=0,xanchor='right',xref='paper',yref='paper'))

coupling1=ToggleButtons(options=['DC','AC','GND'],value='DC',style={'button_width':
  ↪'80px'})
```

```
vscale1=SelectionSlider(options=[0.02,0.05,0.1,0.2,0.5,1,2,5],value=0.
 ↪2,continuous_update=False)
vpos1=FloatSlider(min=-5,max=5,step=0.01,value=0,readout_format='.
 ↪2f',continuous_update=False)

coupling2=ToggleButtons(options=['DC','AC','GND'],value='DC',style={'button_width':
 ↪'80px'})
vscale2=SelectionSlider(options=[0.02,0.05,0.1,0.2,0.5,1,2,5],value=0.
 ↪2,continuous_update=False)
vpos2=FloatSlider(min=-5,max=5,step=0.01,value=0,readout_format='.
 ↪2f',continuous_update=False)

tbase=SelectionSlider(options=[20,50,100,200,500,1000,2000],value=500,continuous_update=False)

capture=Button(description='Capture',button_style='primary')

coupling1_ui=HBox([Label(value='Coupling',layout=Layout(width='105px',display='flex',justify_c
vscale1_ui=HBox([Label(value='Volts/
 ↪Div',layout=Layout(width='105px',display='flex',justify_content='flex-start')),vscale1])
vpos1_ui=HBox([Label(value='Y-Pos.
 ↪',layout=Layout(width='105px',display='flex',justify_content='flex-start')),vpos1])

coupling2_ui=HBox([Label(value='Coupling',layout=Layout(width='105px',display='flex',justify_c
vscale2_ui=HBox([Label(value='Volts/
 ↪Div',layout=Layout(width='105px',display='flex',justify_content='flex-start')),vscale2])
vpos2_ui=HBox([Label(value='Y-Pos.
 ↪',layout=Layout(width='105px',display='flex',justify_content='flex-start')),vpos2])

tbase_ui=HBox([Label(value='Time/Div␣
 ↪( S)',layout=Layout(width='105px',display='flex',justify_content='flex-start')),tbase],layou
 ↪7px 7px 7px'))

osc1=VBox([HTML('<h3 style=\'text-align:center;font-size:14px;margin-top:0px;
 ↪margin-bottom:0px\'>CH1</
 ↪h3>'),coupling1_ui,vscale1_ui,vpos1_ui],layout=Layout(border='solid␣
 ↪2px',margin='5px 5px 5px 5px'))
osc2=VBox([HTML('<h3 style=\'text-align:center;font-size:14px;margin-top:0px;
 ↪margin-bottom:0px\'>CH2</
 ↪h3>'),coupling2_ui,vscale2_ui,vpos2_ui],layout=Layout(border='solid␣
 ↪2px',margin='5px 5px 5px 5px'))
osc3=VBox([tbase_ui,capture],layout=Layout(align_items='center'))
osc_ui=HBox([VBox([fig],layout=Layout(justify_content='space-around')),VBox([osc1,osc2,osc3],l

osc_html='<h1 style=\'text-align:center;font-size:16px;background-color:
 ↪lightgreen\'>Oscilloscope</h1>'
osc_title=HTML(value=osc_html,layout=Layout(width='820px'))
```

```python
def calchar(y,dt,tbase):
    n_avg=5
    y=np.convolve(y,np.ones(n_avg),mode='valid')/n_avg # moving average
    rms=np.sqrt(np.mean(y**2))
    ptp=np.ptp(y)
    if tbase<510:
        y=np.pad(y,(0,int(0.01*len(y)/(10*tbase*1e-6))-len(y)),'constant') # ensure frequency resolution < 100 Hz
    freq=np.abs(np.fft.fftfreq(len(y))[np.argmax(np.abs(np.fft.fft(y-np.mean(y))))]/dt)
    return rms,freq,ptp

def txtchar(ch,rms,freq,ptp):
    text='CH1    ' if ch==1 else 'CH2    '
    text=text+'RMS: {0:6.2f} mV    '.format(rms*1e3) if rms<1 else text+'RMS: {0:6.2f} V     '.format(rms)
    text=text+'Freq: {0:6.3f} kHz    '.format(freq*1e-3) if freq>1e3 else text+'Freq: {0:6.0f} Hz     '.format(freq)
    text=text+'Vpp: {0:6.2f} mV'.format(ptp*1e3) if ptp<1 else text+'Vpp: {0:6.2f} V '.format(ptp)
    return text

def capture_oscscope(empty=None):
    if coupling1.value=='AC' and vscale1.value>0.4:
        print('Only DC coupling is available for V/Div > 0.5. Selecting DC coupling for CH1.')
        coupling1.value='DC'
    if coupling2.value=='AC' and vscale2.value>0.4:
        print('Only DC coupling is available for V/Div > 0.5. Selecting DC coupling for CH2.')
        coupling2.value='DC'
    t,ch1,ch2,_,_=vscope.capture_oscscope(tbase.value,vscale1.value,coupling1.value,vscale2.value,coupling2.value)
    fig.data[0]['x']=fig.data[1]['x']=t
    fig.data[0]['y']=ch1
    fig.data[1]['y']=ch2
    fig.update_layout(xaxis=dict(range=[0,10*tbase.value*1e-6],dtick=tbase.value*1e-6))
    fig.update_layout(yaxis1=dict(range=[vscale1.value*(-vpos1.value-5),vscale1.value*(-vpos1.value+5)]))
    fig.update_layout(yaxis2=dict(range=[vscale2.value*(-vpos2.value-5),vscale2.value*(-vpos2.value+5)]))
    rms1,freq1,ptp1=calchar(ch1,t[1],tbase.value)
    rms2,freq2,ptp2=calchar(ch2,t[1],tbase.value)
```

```
    fig.
↪update_layout(annotations=[dict(text=txtchar(1,rms1,freq1,ptp1)),dict(text=txtchar(2,rms2,f
↪ {0:4.2f} V/Div'.format(vscale1.value)),dict(text='CH2: {0:4.2f} V/Div'.
↪format(vscale2.value)),dict(text=str(tbase.value)+'  s/Div')])

capture_oscscope()

capture.on_click(capture_oscscope)
tbase.observe(capture_oscscope,'value')
vscale1.observe(capture_oscscope,'value')
vpos1.observe(capture_oscscope,'value')
coupling1.observe(capture_oscscope,'value')
vscale2.observe(capture_oscscope,'value')
vpos2.observe(capture_oscscope,'value')
coupling2.observe(capture_oscscope,'value')
```

[ ]:
```
display(ps_title,ps_ui)
display(wg_title,wg_ui)
display(osc_title,osc_ui)
```

```
HTML(value="<h1 style='text-align:center;font-size:16px;background-color:
↪lightcoral'>Dual DC Voltage Supply</h…
```

```
HBox(children=(HBox(children=(Label(value='VDCP/VDCN (±V)',␣
↪layout=Layout(width='105px')), FloatSlider(value=5…
```

```
HTML(value="<h1 style='text-align:center;font-size:16px;background-color:
↪lightblue'>Waveform Generator</h1>", …
```

```
HBox(children=(VBox(children=(HTML(value="<h3 style='text-align:center;font-size:
↪14px;margin-top:0px;margin-bo…
```

```
HTML(value="<h1 style='text-align:center;font-size:16px;background-color:
↪lightgreen'>Oscilloscope</h1>", layou…
```

```
HBox(children=(VBox(children=(FigureWidget({
    'data': [{'name': 'CH1',
              'type': 'scatter',
   …
```

0.1 Waveform Generator DC Offset calibration

W1 DC Bias: 0.141V

W2 DC Bias: 0.101V

```
self.p1={0.02 :{'gain':224,'amp':0.0950,'dc':2,'dco':130,'dco_c2':171,'aco_c2':-0.005},
         0.05 :{'gain':208,'amp':0.1500,'dc':1.91,'dco':130,'dco_c2':168,'aco_c2':-0.000},
         0.1  :{'gain':160,'amp':0.3900,'dc':1.83,'dco':130,'dco_c2':159,'aco_c2':-0.020},
         0.2  :{'gain':138,'amp':0.5500,'dc':1.81,'dco':130,'dco_c2':157,'aco_c2':-0.050},
         0.5  :{'gain':220,'amp':2.1700,'dc':2.06,'dco':130,'dco_c2':130,'aco_c2':-0.000},
         1    :{'gain':212,'amp':2.8500,'dc':2.0,'dco':130,'dco_c2':130,'aco_c2':-0.000},
         2    :{'gain':160,'amp':7.9000,'dc':1.85,'dco':130,'dco_c2':130,'aco_c2':-0.000},
         5    :{'gain':106,'amp':19.100,'dc':1.81,'dco':130,'dco_c2':130,'aco_c2':-0.000}}
self.p2={0.02 :{'gain':224,'amp':0.0950,'dc':2.03,'dco':130,'dco_c2':171,'aco_c2':-0.025},
         0.05 :{'gain':208,'amp':0.1500,'dc':1.93,'dco':130,'dco_c2':167,'aco_c2':-0.020},
         0.1  :{'gain':160,'amp':0.3900,'dc':1.84,'dco':130,'dco_c2':159,'aco_c2':-0.040},
         0.2  :{'gain':138,'amp':0.5500,'dc':1.82,'dco':130,'dco_c2':158,'aco_c2':-0.070},
         0.5  :{'gain':220,'amp':2.1700,'dc':2.08,'dco':130,'dco_c2':130,'aco_c2':-0.000},
         1    :{'gain':212,'amp':2.8500,'dc':2.02,'dco':130,'dco_c2':130,'aco_c2':-0.000},
         2    :{'gain':160,'amp':7.9000,'dc':1.86,'dco':130,'dco_c2':130,'aco_c2':-0.000},
         5    :{'gain':106,'amp':18.800,'dc':1.81,'dco':130,'dco_c2':130,'aco_c2':-0.000}}
```

0.2 Oscilloscope DC offset calibration

0.2.1 Calibration Result

Completed calibrating 0.02 V/Div

Completed calibrating 0.05 V/Div

Completed calibrating 0.1 V/Div

Completed calibrating 0.2 V/Div

Completed calibrating 0.5 V/Div

Completed calibrating 1 V/Div

Completed calibrating 2 V/Div

Completed calibrating 5 V/Div

‘dc’ CH1 0.02 V/Div: 2.0

‘dc’ CH1 0.05 V/Div: 1.91

‘dc’ CH1 0.1 V/Div: 1.83

‘dc’ CH1 0.2 V/Div: 1.81

‘dc’ CH1 0.5 V/Div: 2.06

‘dc’ CH1 1 V/Div: 2.0

‘dc’ CH1 2 V/Div: 1.85

‘dc’ CH1 5 V/Div: 1.81

‘dc’ CH2 0.02 V/Div: 2.03

‘dc’ CH2 0.05 V/Div: 1.93

‘dc’ CH2 0.1 V/Div: 1.84

‘dc’ CH2 0.2 V/Div: 1.82

‘dc’ CH2 0.5 V/Div: 2.08

‘dc’ CH2 1 V/Div: 2.02

‘dc’ CH2 2 V/Div: 1.86

‘dc’ CH2 5 V/Div: 1.81

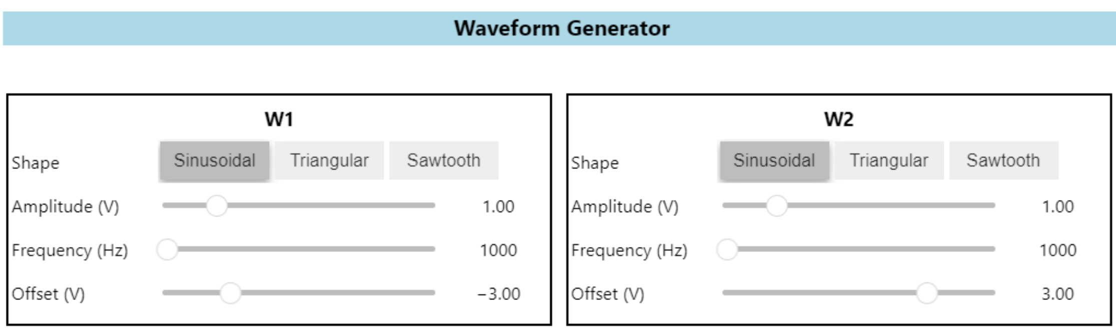
```
self.p1={0.02 :{'gain':224,'amp':0.0950,'dc':2,'dco':130,'dco_c2':171,'aco_c2':-0.005},
         0.05 :{'gain':208,'amp':0.1500,'dc':1.91,'dco':130,'dco_c2':168,'aco_c2':-0.000},
         0.1  :{'gain':160,'amp':0.3900,'dc':1.83,'dco':130,'dco_c2':159,'aco_c2':-0.020},
         0.2  :{'gain':138,'amp':0.5500,'dc':1.81,'dco':130,'dco_c2':157,'aco_c2':-0.050},
         0.5  :{'gain':220,'amp':2.1700,'dc':2.06,'dco':130,'dco_c2':130,'aco_c2':-0.000},
         1    :{'gain':212,'amp':2.8500,'dc':2.0,'dco':130,'dco_c2':130,'aco_c2':-0.000},
         2    :{'gain':160,'amp':7.9000,'dc':1.85,'dco':130,'dco_c2':130,'aco_c2':-0.000},
         5    :{'gain':106,'amp':19.100,'dc':1.81,'dco':130,'dco_c2':130,'aco_c2':-0.000}}
self.p2={0.02 :{'gain':224,'amp':0.0950,'dc':2.03,'dco':130,'dco_c2':171,'aco_c2':-0.025},
         0.05 :{'gain':208,'amp':0.1500,'dc':1.93,'dco':130,'dco_c2':167,'aco_c2':-0.020},
         0.1  :{'gain':160,'amp':0.3900,'dc':1.84,'dco':130,'dco_c2':159,'aco_c2':-0.040},
         0.2  :{'gain':138,'amp':0.5500,'dc':1.82,'dco':130,'dco_c2':158,'aco_c2':-0.070},
         0.5  :{'gain':220,'amp':2.1700,'dc':2.08,'dco':130,'dco_c2':130,'aco_c2':-0.000},
         1    :{'gain':212,'amp':2.8500,'dc':2.02,'dco':130,'dco_c2':130,'aco_c2':-0.000},
         2    :{'gain':160,'amp':7.9000,'dc':1.86,'dco':130,'dco_c2':130,'aco_c2':-0.000},
         5    :{'gain':106,'amp':18.800,'dc':1.81,'dco':130,'dco_c2':130,'aco_c2':-0.000}}
```

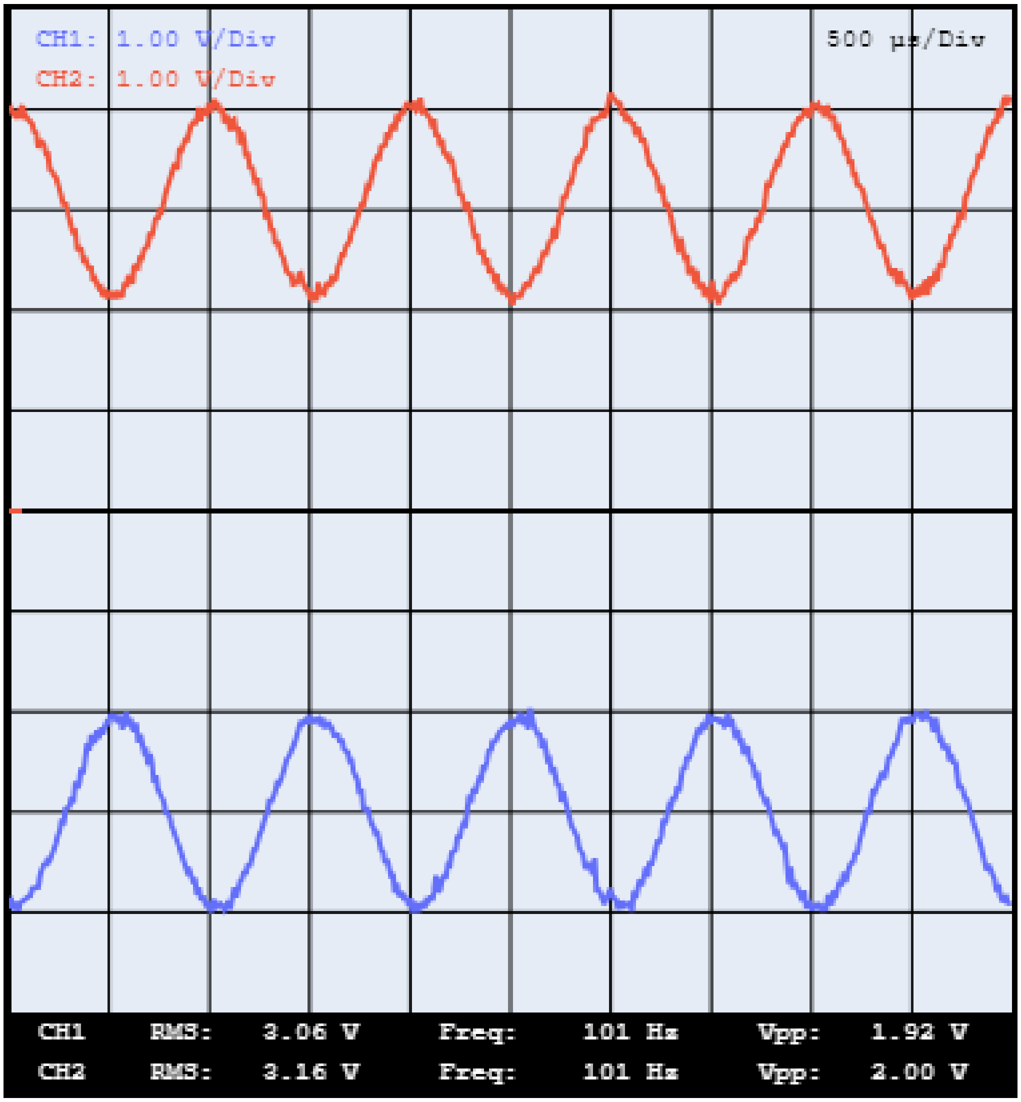
0.3 Results after calibration

0.3.1 Checking DC offsets

CH1 reads W1

CH2 reads W2





0.4 Open-ended Question

'amp' is the amplification of V/div of the oscilloscope

'dc' is the DC Bias of 'CH1' and 'CH2' that was detected through the calibration process for various V/div

vscope.p1[vdiv]['dc'] and vscope.p2[vdiv]['dc'] represent the DC offsets set for CH1 and CH2 respectively for the given voltage division vdiv.

np.mean(y1) and np.mean(y2) represent the mean of the captured data for CH1 and CH2 respectively.

vscope.p1[vdiv]['amp'] and vscope.p2[vdiv]['amp'] represent the amplification factors or gains set for CH1 and CH2 respectively for the given voltage division vdiv.

1. First, it captures oscilloscope data for both channels (ch1 and ch2) multiple times (n_calibrate times) for each voltage division (vdiv) specified in vdiv_list.

2. It averages the captured data (y1 and y2) over the calibration iterations.
3. Then, it calculates the DC bias for each channel (ch1_dc and ch2_dc) using the following formula:

- CH1:
  - ch1_dc[i]=vscope.p1[vdiv][dc]− np.mean(y1)/vscope.p1[vdiv][amp]
- CH2:
  - ch1_dc[i]=vscope.p1[vdiv][dc]− np.mean(y1)/vscope.p1[vdiv][amp]

This formula adjusts the DC bias based on the mean of the captured data for each channel and the amplification factor set for each channel at a specific voltage division.