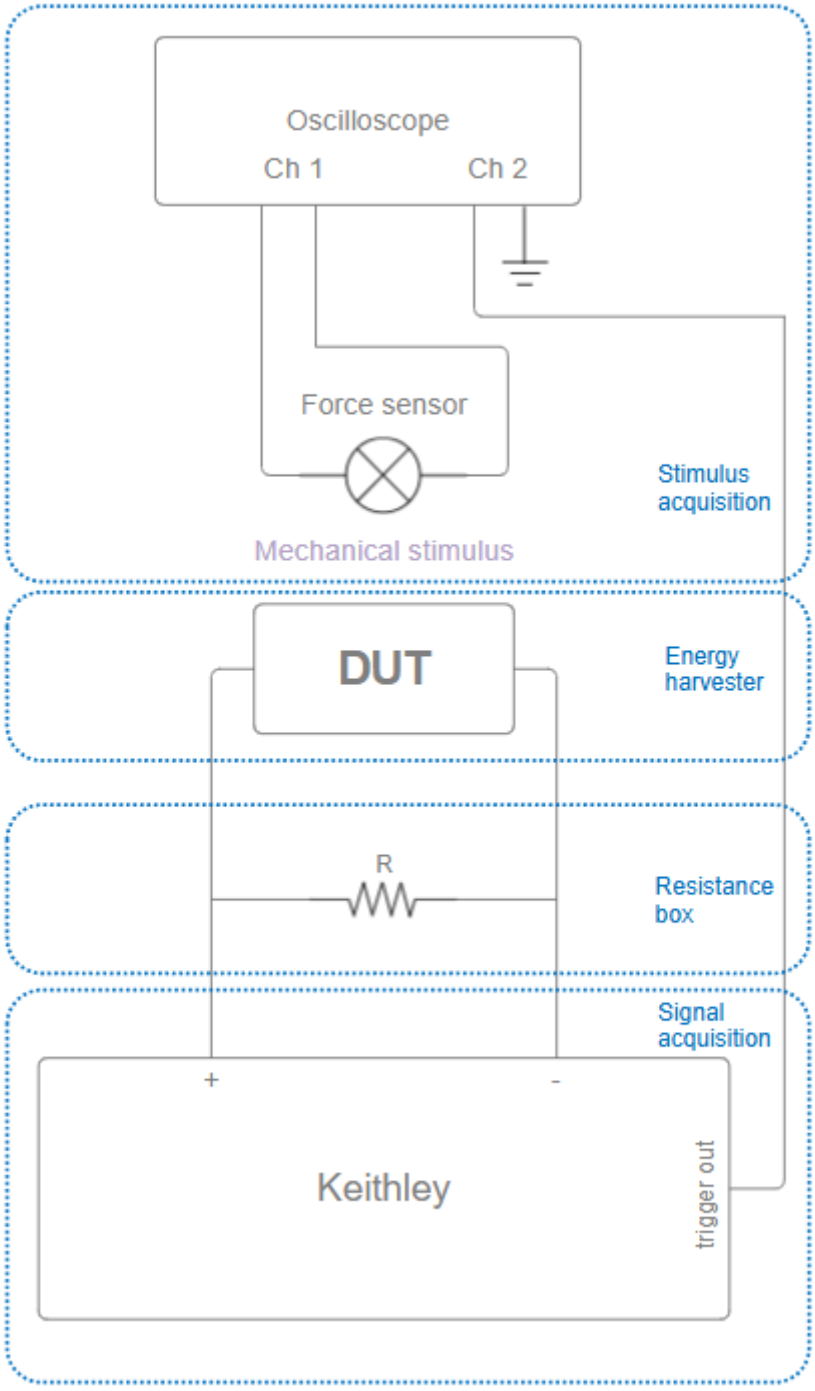
Data acquisition example: Keithley and oscilloscope

This data acquisition example has been tested using a Keithley 2635A and an oscilloscope Tektronix TBS 1000B Series, but should be applicable for other Keithley based on TSP-link via TSB or other oscilloscopes based on SCPI communication.

Setup circuit schematic



The Device Under Test was a Triboelectric nanogenerator in which movement stimuli were applied thanks to a magnetic shaker and recorded on the oscilloscope. In order to synchronize stimulus and data streams, a trigger feedback signal was added by connecting the digital output pin 14 of the Keithley to the oscilloscope. The convention of that signal was taken as high (5V) during the Keithley acquisition and low (0V) otherwise.

Code explanation:

The file `'Keithley263x_and_oscilloscope.py'` queries the voltage measurements of the Keithley 2635A, outputs the trigger signal while acquiring and queries the simultaneous measurement of channel 1 and channel 2 of the oscilloscope thanks to Python's library pyvisa. Therefore, for this file to be executed, python3 software is required (i.e. anaconda release), as well as the installation of the drivers to connect to the Keithley and oscilloscope.

If python is added to the environment path in the operating system, NanoDataLyzer application can take advantage of python execution (if the version is compatible) and directly query for data to the oscilloscope, automatically performing the measurements.

The file `'Measure_K263xVolt_and_oscilloscope_Prompt.ndl'` contains the following code under Matlab syntax (editable by opening it on *Tools>Create Dataset Batch* choosing the file with *Import from dataset* button):

Look for all the available instruments connected and get their information and addresses. The file `'AvailableInstrumentsList.py' queries for that.`

```
[a,i]=pyrunfile("AvailableInstrumentsList.py",{'address','info'});
info=cell(i);
address=cell(a);
```

Compare the information instruments found with the target instruments the acquisition was designed for, in this case Keithley models 2635 or 2636, and Tektronix oscilloscope. If there is only one instrument for the target characteristics, it directly extracts its address. Otherwise, it asks the user which instrument should be considered and lists the information in a prompt dialog.

```
model=zeros(size(info));
scopemodel=zeros(size(info));
str='';
for k=1:numel(model)
    str=sprintf('%s%s\n%s\n\n',str,string(address{k}),string(info{k}));
    if contains(string(info{k}),'KEITHLEY','IgnoreCase',true)&&contains(string(info{k}),'MODEL 263',
            'IgnoreCase',true);
        model(k)=1;
    end
end
if sum(model)==1
    ADDRESS=string(address{find(model)});
else
    ADDRESS=inputdlg({sprintf('Choose the Keithley:\n%s',str)},'Keithley address',[1 45],
{char(string(address{end}))});
    if isempty(ADDRESS)
        return;
    end
end
```

```
str='';
for k=1:numel(scopemodel)
    str=sprintf('%s%s\n%s\n\n',str,string(address{k}),string(info{k}));
    if contains(string(info{k}),'TEKTRONIX','IgnoreCase',true)&&contains(string(info{k}),'TBS 1',
        'IgnoreCase',true);
       scopemodel(k)=1;
    end
end
if sum(scopemodel)==1
    ADDRESS2=string(address{find(scopemodel)});
else
    ADDRESS2=inputdlg({sprintf('Choose the scope:\n%s',str)},'Oscilloscope address',[1
45],{char(string(address{end}))});
    if isempty(ADDRESS2)
        return;
    end
end
```

In order to select the measurement parameters, it starts a set of default values, but it also checks if it exists a file 'paramsKeithley263xVoltage.txt' with the last used parameters and reads its values.

```
defaults={'10','0.1','0.05','5','4','1e-9'};
if exist('paramsKeithley263xVoltage.txt','file')
    fid=fopen('paramsKeithley263xVoltage.txt');
    tline = fgetl(fid);
    try
        defaults=eval(tline);
        defaults(7:end)=[];
    catch ME
    end
    fclose(fid);
end
```

Input the user measurement parameters using a dialog prompt and update the last used parameters file 'paramsKeithley263xVoltage.txt'.

```
T=inputdlg({'Duration of measurement in seconds:','Time step between measurements','Time
resolution (lower than time step):','Voltage range:','Voltage limit (lower than
range):','Current range:'},'Parameters of the measurement',[1 45;1 45;1 45;1 45;1 45;1
45],defaults);
if isempty(T)
    return;
end

fid=fopen('paramsKeithley263xVoltage.txt','w');
fprintf(fid,'{''%s'',''%s'',''%s'',''%s'',''%s'',''%s''}',T{:});
fclose(fid);
```

Execute the python file 'Keithley263x_and_oscilloscope.py' to perform the measurement and variables 'out', 'ch1', 'ch2' and 't' will store the data from the Keithley and voltages of each channel and time from the oscilloscope. These variables must be converted to numerical row arrays using the command 'double'.

```
Timespan=T{1};
Tstep=T{2};
Tres=T{3};
Vrange=T{4};
Vlimit=T{5};
Irange=T{6};
[out,ch1,ch2,t]=pyrunfile(sprintf('Keithley263x_and_oscilloscope.py %s %s %s %s %s %s %s
%s',ADDRESS2,ADDRESS,Timespan, Tstep, Tres, Vrange, Vlimit,
Irange),{'out','scaled_wave1','scaled_wave2','scaled_time'});
```

Eventually, the final values are passed by storing the data in variables with the proper keyword name. For the force sensor data, ‘dataStimulus’ should contain a matrix array composed of the column arrays time and voltage of channel 1 and time and voltage of channel 2 if necessary (in this case channel 2 contains the trigger information). ‘channel='CH 1'’ indicates that the stimulus data was measured in channel 1, and ‘Trigger=true’ indicates that the signal is expected to be synchronized using the trigger data. ‘operation='none'’ indicates that the stimulus data reading doesn’t need any transformations to become the force value (transducer gain of 1), and ‘stimulusLabel='F(N)' for the name and units of the stimulus. ‘data’ will be the outpuf of the energy harvester measured on the Keithley.

```
dataStimulus=[double(t)',double(ch1)'./22.5e-3,double(t)',double(ch2)'];
channel='CH 1';
Trigger=true;
operation='none';
stimulusLabel='F(N)';
data=double(out);
```