SMART MATERIAL

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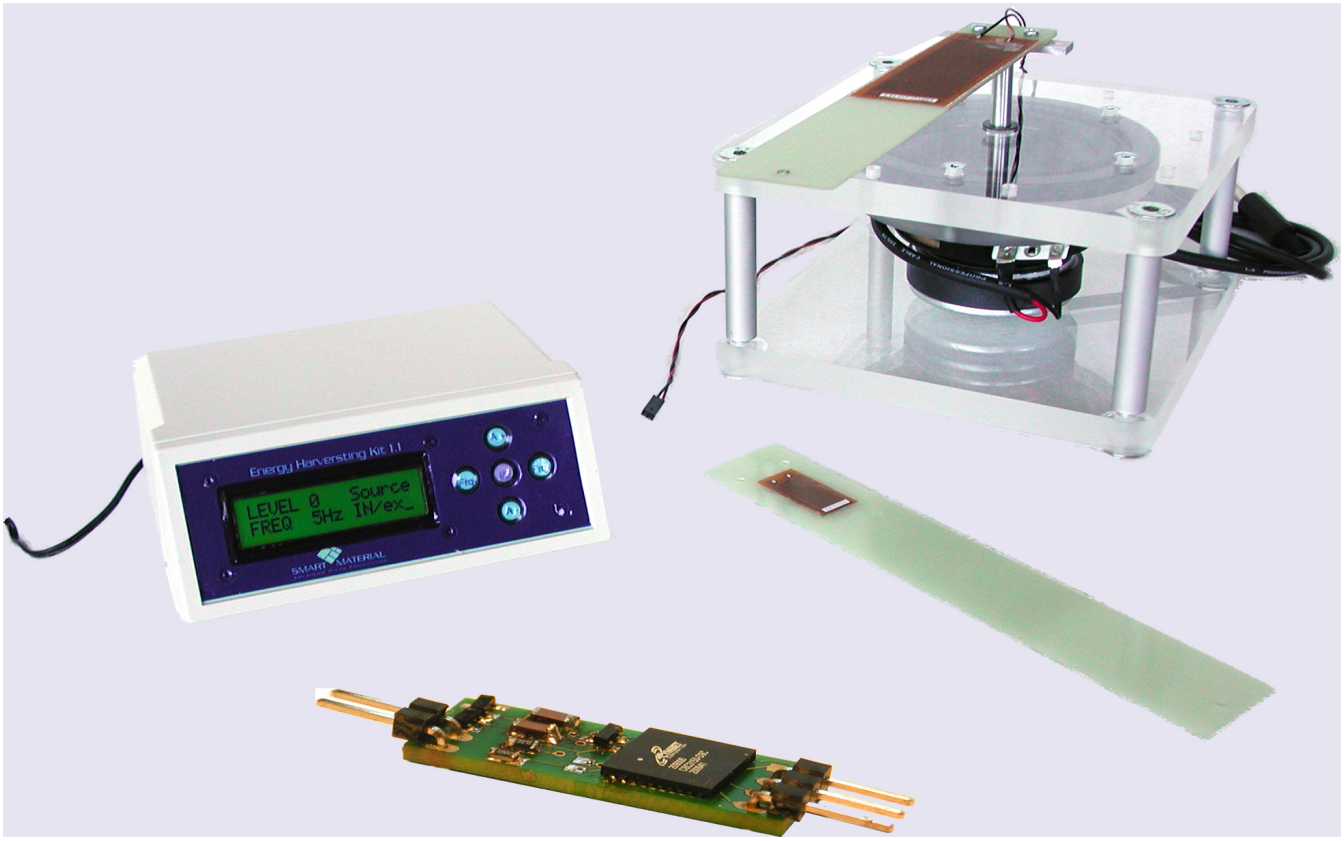

Energy Harvesting Kit V1.3

EXPERIMENTAL PROTOCOL

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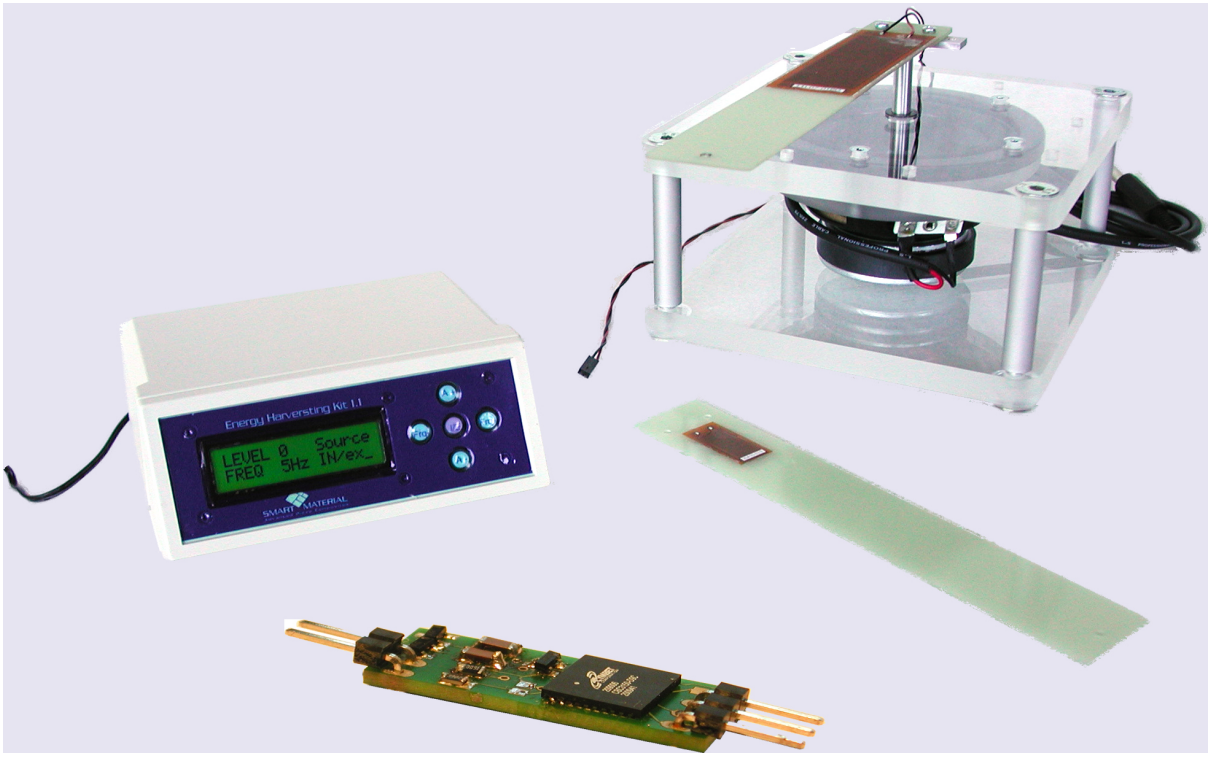
INTRODUCTION



Experimental Setup

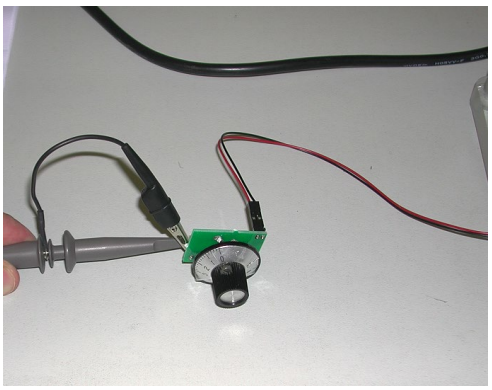
Set up your Energy Harvesting Kit using these steps:

- Mount the MFC on the shaker
- Plug the shaker in to the Audio / Out plug of the Amplifier Module
- Connect the Amplifier Module with the Power Plug “12V in”

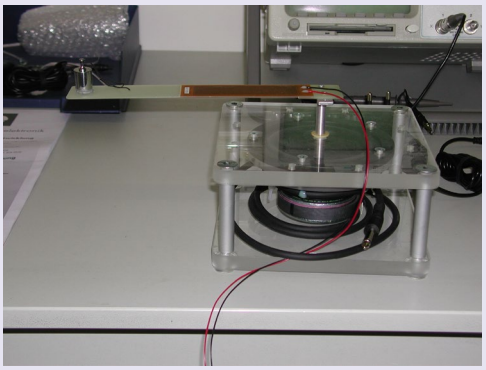
MEASURING INPUT IMPEDANCE

Measurement Setup

- Connect the **MFC** to the **VIM** (Variable Impedance Module)



- Connect the output of the VIM to an **oscilloscope** or a **multimeter**
- Measure the peak-to-peak or **effective Value Output** voltage measurement of the VIM for various **resistor values** and note your results in the chart on **page 5** (or copy the chart to an Excel file and note your results there to simplify the evaluation).
- Repeat this experiment with different frequencies, different amplifier levels, and different MFCs to get to know the behavior of the MFC.
- Plot the result in **Voltage and Power** versus **Time**.



Note: At some frequencies the amplitude of the beam will be very low.

You can fix a **piece of mass** (20g – 50g) at the end of the beam to get higher amplitudes (see: **Instructions For Use**).

Experiment

Behavior of the **MFC 8528** using different frequencies and different amplifier levels:

Level =		MFC 8528 @ Frequency [Hz]											
		10		15		20		25		30		35	
		Veff	P	Veff	P	Veff	P	Veff	P	Veff	P	Veff	P
R [kΩ]	5	x	X	x	x								
	10	x	X	x	x								
	15	x	X										
	20	x	X										
	25	x	X										
	30												
	35												
	40												
	45												
	50												
	55												
	60												
	65											x	x
	70											x	x
	75											x	x
	80									x	x	x	x
	85									x	x	x	x
	90									x	x	x	x
	95									x	x	x	x
	100									x	x	x	x

Behavior of the **MFC 2814** using different frequencies and different amplifier levels:

Level =		MFC 2814 @ Frequency [Hz]											
		10		15		20		25		30		35	
		Veff	P	Veff	P	Veff	P	Veff	P	Veff	P	Veff	P
R [kΩ]	50	x	x	x	x								
	100	x	x	x	x								
	150	x	x										
	200	x	x										
	250	x	x										
	300												
	350												
	400												
	450												
	500												
	550												
	600												
	650											X	x
	700											X	x
	750											X	x
	800									X	x	X	x
	850									X	x	X	x
	900									X	x	X	x
	950									X	x	X	x
	1000									X	x	X	x

ACCUMULATED ENERGY

Measurement Setup

- Connect the **MFC** to the **Smart Module** at "MFC in" (if the VIM is still connected, disconnect it first)
- Choose a capacitor: 1- external custom capacitor, 2- 0.1F Gold Cap, 3- 22μF Tantal Cap, 4- 470μF Electrolyte Cap (see **User Manual**)
- Connect the output of the **Smart Module** to an **oscilloscope** (the multimeter is only useful for the Gold Cap)
- Discharge the capacitor by pressing the black button. Check with the voltmeter that **zero voltage** has reached
- Switch on the Energy Harvesting Kit at the required level and frequency
- Map the **Voltage – Time** curve with the oscilloscope

The maximum capacitor voltage of the small **Ceramic Cap** is reached very fast (after approximately 1 second), so don't stop the measurement by stopping the oscilloscope. Instead press the black discharge button for about 1 second after the start of the experiment.

Useful measuring time intervals for the different **capacitors**:

Cap	Gold Cap (0.1F)	Tantalum Cap (22μF)	Electrolyte Cap (470μF)
Time Interval	30 seconds	0.5 seconds	5 seconds

!!Attention!! Be aware that the voltage should not exceed maximum capacitor voltage levels, especially for the **Gold Cap** with 5V.

Calculation

The stored energy after a defined acquiring period is given by

$$W(t) = \frac{1}{2} C(V(t))^2$$

(where W=watts, t=time, c= capacitance)

Experiment

Draw the following **Energy – Time** diagram to visualize what this relation means:

MFC 8528 @ 470uF , Level …. , Frequency ….

T [s]	0	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7
V															
W															

Now we have charged a capacitor; discharge it before performing the next step.

SELF-DISCHARGE OF STORAGE CAPACITORS

Measurement Setup

- Connect the MFC to the **Smart Module** at “MFC in” (if the VIM is still connected, disconnect it first)
- Choose a capacitor: 1- external custom capacitor, 2- 0.1F Gold Cap, 3- 22μF Tantal Cap, 4- 470μF Electrolyte Cap
- Connect the output of the Smart Module to an oscilloscope (the multimeter is only useful for the Gold Cap)
- Charge the capacitor to 5V (Gold Cap: 2V) by using the **Power Amplifier** or simply tipping the MFC
- Make sure that your voltage measurement equipment has a high input impedance (≥ 10MΩ)
- The discharging time for the bigger capacitors can be very long (especially for the Gold Cap), therefore we recommend doing this experiment only for the Tantalum Cap. If you still want to do the experiment with the other capacitors, the following table might help you to choose a data reading time interval.

Useful time intervals for the different capacitors:

Cap	Gold Cap (0.1F)	Tantalum Cap (22μF)	Electrolyte Cap (470μF)
Time Interval	1 day	10 s	300

Calculation

The discharge resistor can be calculated by the formula

$$R_{discharge} = \frac{\tau}{C}$$

(Where τ is the time of the capacitor's voltage level drop to 37% of initial value.)

Experiment

You can draw the **Voltage - Time** curve to see the exponential discharging behaviour of capacitance.

C = 22uF V (0)= ….

T [s]	0	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7
V															

SMART EH MODULE / CL-50

Measurement Setup

Two themes will give you examples of energy harvesting engineering.

1. Which effectiveness shows the Smart Module, CL-50, providing energy for a certain application, which consumes only 3.3V@ …kΩ ?
2. How long does it take for electrical energy to generate that can run an application which requires 3.3V @ 10 mA for 10ms?

Experiment

Make theoretical and practical comparisons and note your measurements using **Time --- Voltage.**

MFC 8528 @ **470µF** , @ ….. Hz @ Level 2

Time	0	10	20	30	40	50	60
Voltage							
Energy							

MFC 8528 @ **CL-50** , @ ….. Hz @ Level 2

Time	0	10	20	30	40	50	60
Voltage							
Energy							

CONNECT WITH US

We feature our popular **in-depth tutorial** on **Energy Harvesting** on our YouTube channel:

https://www.youtube.com/watch?v=CNSTzSfVckU

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