KLL engineering

Play with

ARDUINO

OPERATING MANUAL
FOR
POWER_meter_FFT_V04 (.zip)

by KLL-engineering on 3.4.2012
(v 0.4b)

Some time ago I play with a Arduino, recording GRID VOLT and AMP
and did a project with 5 lines (1 Volt (230 Vrms), 5 Currents (5Arms)),
in 3 versions,

- with a dataexport to Processing for SCOPE function,
- with datarecording by SD card,
- SD card and GPRS shield send ALARM and DATA SMS.

For more info pls see arduino.isgreat.org

Recently I was asked about the FFT feature in Processing or if it would be possible to do it online in
the Arduino.

So this project was born.
I try a combination of the EMON software, the FIX-FFT software, my USB MENU,
the Processing sketch SCOPE from David Konsumer using controlP5 lib
and my ZOOM window (button)

1. **Get the Code**
I work with WIN 7,
ARDUINO 1.0 (on ARDOINO UNO),   http://arduino.cc/en/Main/Software
Processing 1.5.1.   http://processing.org/download/

and pack projects (if required with libraries) to a ZIP file.
Please download it from the DOWNLOAD menu or from the CODE link inside the BLOG about
ARDUINO PROJECT: POWER METER
from my work blog website arduino.isgreat.org

2. **Unpack**
get the subdirectory POWER_meter_FFT_V04\Arduino\POWER_meter_FFT_v04 from ZIP
to your Arduino sketch path

**get the subdirectory POWER_meter_FFT_V04\Processing\POWER_meter_FFT_v04 from ZIP
to your Processing sketch path**

pls. testcompile both.

    3. upload Arduino sketch to ARDUINO UNO...
and find under DONE UPLOADING
Binary sketch size: 16708 bytes (of a 32256 byte maximum)

NOW start the terminal function (by Arduino terminal (incl. Reset))
and adjust: autoscroll, No line ending, 115200 baud

or other terminal software like HTERM...
same COM port like for uploading (Arduino Terminal (and Processing run) closed)
Baud 115200. data 8, stop 1, parity none, CTS OFF

    4. menu operation
at start, reset, arduino terminal start, you see following boot info:

kll-engineering on ARDUINO
  EMON POWER meter, FFT
hit BLANK ENTER
Vcc: 4918 mV

focus / mouse pointer on input field, on keyboard use [blank/space][Enter] to get the menu:

_____
  kll-engineering on ARDUINO
  EMON POWER meter, FFT V0.4

_____
0 reset conti jobs and output
____ TOGGLE ON OFF what function you need _____
1 EMON
2 FFT
3 with serial print A0
4 with serial print A0,A1
____ Tools_____
6 show sampling and calc timing
7 measure A0 .. A5
____ adjust EMON and FFT _____
8 FFT delay
9 EMON samples
_____ more function but not to be used from here _____
5 start data send to OSCI   (only by processing sketch)
c zoom data analog channel set (only by processing sketch)
z zoom data for OSCI function (only by processing sketch)
_____ utilities _____
a: ASCII list / d: toggle diagnostic / t: time / s: variables

_____
select:

**because that is not a EMON project only, more a tool for analyzing GRID POWER,
the default is ALL OFF.**
**The menu operation uses the terminal input field (focus by mouse)
and you type ONE of the following characters and use [Enter].**

– 0

if you dont want to use the reset button and dont know what all is enabled, this menu entry allows to disable again all features.

– 1

the EMON software is started, doing batch 3000 readings of A0 (VOLT) A1 (CURRENT)
and calculate online filters... and at the end of the reading batch calculates
Watt, VA, powerfactor, Vrms, Irms   (here a example without measuring hardware)

 W , VA , p , Vrms , Irms
, 273.55, 273.87, 1.00, 190.92, 1.43,
, 0.02, 0.10, 0.21, 0.85, 0.12,
, 0.02, 0.10, 0.18, 0.84, 0.12,
, 0.02, 0.10, 0.17, 0.84, 0.12,

now in rev 0.4 with Frequency calculation

, W , VA , p , Vrms , Irms, Freq
, 271.03, 275.99, 0.98, 190.65, 1.45, 49.89,
, 0.04, 0.27, 0.14, 41.25, 0.01, 50.12,
, 0.05, 0.26, 0.18, 40.85, 0.01, 50.11,
, 0.05, 0.26, 0.19, 41.11, 0.01, 50.13,

pls note that the values are separated by comma, a SAVE TO FILE, EDIT, SAVE parts to EMON_DATA.CSV
allows you to use that values later in EXCEL... for further processing.

 (pls see [4],[6],[9] for more options)

– 2

the measuring data from A0 (VOLT) are stored to a 128 long array of type Character (BYTE)
Ain 0 .. 1023 are reduced to -128 … 127 (int to byte)
a time delay between the measurements allows a adjustment (option [8])
of the base frequency.
 Then a FFT calculation gives 64 amplitudes (offset, base, 2 base, 3 base, …)

FFT ,
5,0,75,1,5,1,18,1,2,0,6,1,2,1,2,1,1,0,0,1,1,1,1,1,0,0,1,1,0,1,1,0,1,0,1,1,1,1,0,1,1,0,1,1,0,1,2,1,1,0,1,1,0,1,0,1,1,
0,1,1,1,1,1,0,

from rev 0.4 see 2 long lines,
- list of frequenzies calculated by used msec for sampling,
- list of amplitudes (FFT result 64 values (at 128 samples))

FFT
Hz,0,25,50,75,100,125,150,175,200,225,250,275,300,325,350,375,400,425,450,475,500,525,550,575,600,62
5,650,675,700,725,750,775,800,825,850,875,900,925,950,975,1000,1025,1050,1075,1100,1125,1150,1175,1
200,1225,1250,1275,1300,1325,1350,1375,1400,1425,1450,1475,1500,1525,1550,1575,
FFT
amp,11,1,74,1,7,1,15,1,1,1,2,1,0,1,1,1,3,1,0,1,2,1,1,1,1,1,1,1,0,1,1,0,1,1,1,0,1,1,1,1,1,1,1,1,1,1,1,1,0,1,0,1
,1,1,1,1,1,1,1,1,0,

 (pls see [1],[3],[8] for more options)

– 3

with this option a extra line with the sample value for A0 is printed.
Like for FFT [2] AND [3] give

..128 lines..
text, sample#, measuring value A0 / 4 - 128
FFTsample,115,-99,
FFTsample,116,-103,
FFTsample,117,-107,
FFTsample,118,-110,
FFTsample,119,-113,
FFTsample,120,-116,
FFTsample,121,-119,
FFTsample,122,-121,
FFTsample,123,-122,
FFTsample,124,-124,
FFTsample,125,-125,
FFTsample,126,-126,
FFTsample,127,-126,
FFT ,
85,0,19,0,1,0,0,0,1,0,0,0,1,0,1,0,1,0,1,0,1,0,0,0,1,0,0,0,1,0,1,0,1,0,2,0,1,0,0,0,1,0,0,0,1,0,1,1,1,1,1,0,1,0,0,0,1,
0,0,0,1,0,0,1,

–
–
– 4

with this option a extra line with the sample value for A0 and A1 is printed.
Like for EMON [1] AND [4] give

.. 3000 lines.. , A0, A1
,351,352
,344,338
,317,305
,272,254
,203,180
,135,112
,67,47
,12,0
,0,0
,0,0
,0,0
,0,0
,0,3
,17,28
,55,71
, 0.05, 0.26, 0.19, 41.11, 0.01, 50.13,

pls note the big difference between the 2 ways of measuring of EMON and FFT,
while EMON samples are not saved to a memory array, the sample print out must be between the
samples, means this option [3],[4] on [1] changes the sample rate of the EMON samples and with this
the result!!, but with FFT I first sample to the array, and then print (offline) the array values, and so
the sample rate is not influenced by sample print out, only the batch frequenzy is slower.


– 6

with this feature I try to check on the sample timing..
it is used for all 3 jobs (EMON, FFT, SCOPE), for sampling and calculation separate,

but its quality is questionable,
-?- how accurate is the Arduino millis() function (and crystal...).
-?- on a fast job like FFT the millis is a round ?UP?DOWN? With 1 millisecond error to expect.
But it helps anyway to understand the timing and spec. about the problems mentioned in [4].
 For the SCOPE ZOOM function the needed milliseconds for a 512 batch is send to Processing and used for the FFT Hz calibration there.
One line for FFT with the option [6] shows now
FFT sampling
sampling #, 128 , millis:,40 , 3200.00, Hz
FFT calc and print
FFT ,
91,1,17,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,0,1,1,1,1,1,1,1,0,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,
1,1,1,1,1,1,0,
calc millis: 23

now in rev 0.4 a list of the frequencies, a very long line.

FFT sampling
,sampling #, 128 , millis:,40 , 3200.00, Hz
FFT calc and print
FFT
Hz,0,25,50,75,100,125,150,175,200,225,250,275,300,325,350,375,400,425,450,475,500,525,550,575,600,62
5,650,675,700,725,750,775,800,825,850,875,900,925,950,975,1000,1025,1050,1075,1100,1125,1150,1175,1
200,1225,1250,1275,1300,1325,1350,1375,1400,1425,1450,1475,1500,1525,1550,1575,
FFT
amp,69,1,33,1,1,1,1,1,0,1,0,1,0,1,1,2,1,1,0,1,1,1,1,1,0,1,0,1,0,1,0,1,0,1,1,1,1,1,1,1,0,1,0,1,0,1,1,2,1,1,0,1,1,1,
1,1,0,1,0,1,0,1,1,0,
,calc millis:, 48   ! 25msec more for that extra long lines printout

One line for EMON with the option [6] shows now

, EMON sampling
sampling #, 3000 , millis:,1082 , 2772.64, Hz
EMON calc and print
192.08, 189.60, 1.01, 158.37, 1.20,
calc millis: 5

now rev 0.4 with calculating GRID Frequency also
, EMON sampling
sampling #, 3000 , millis:,1158 , 2590.67, Hz
EMON calc and print
0.05, 0.22, 0.23, 35.86, 0.01, 50.16,
calc millis: 4

but also slower, from 1082 up to 1158 msec for a EMON batch of 3000.

    –   7
just check on the 6 Arduino analog inputs,
Vcc, A0,A1,A2,A3,A4,A5   here A0 on 3V3 and A2 on V5, other channels floating

4897 mV 695 , 658 , 1023 , 1000 , 968 , 937 of 1024
4897 mV 695 , 756 , 1023 , 1011 , 990 , 950 of 1024
4897 mV 696 , 809 , 1023 , 1022 , 1009 , 968 of 1024
4897 mV 696 , 776 , 1023 , 1021 , 1018 , 992 of 1024
4897 mV 696 , 689 , 1021 , 1012 , 1008 , 1002 of 1024

4897 mV 696 , 601 , 1023 , 999 , 988 , 993 of 1024
4897 mV 695 , 541 , 1023 , 989 , 965 , 972 of 1024
4897 mV 696 , 566 , 1023 , 989 , 955 , 949 of 1024
4897 mV 695 , 636 , 1023 , 998 , 963 , 940 of 1024
4897 mV 696 , 735 , 1023 , 1008 , 985 , 946 of 1024
4897 mV 696 , 804 , 1023 , 1020 , 1005 , 964 of 1024
4897 mV 697 , 789 , 1023 , 1022 , 1018 , 989 of 1024
4897 mV 696 , 714 , 1023 , 1015 , 1012 , 1000 of 1024

**The FFT batch reads 128 samples and transform values to BYTE, this calculation already slows
it down from 8900Hz (best timing for not modified Arduino Ain and save to integer array) to 7760Hz.
But as we only have 128 samples in array what we see?
Here a simulation to help me with it**
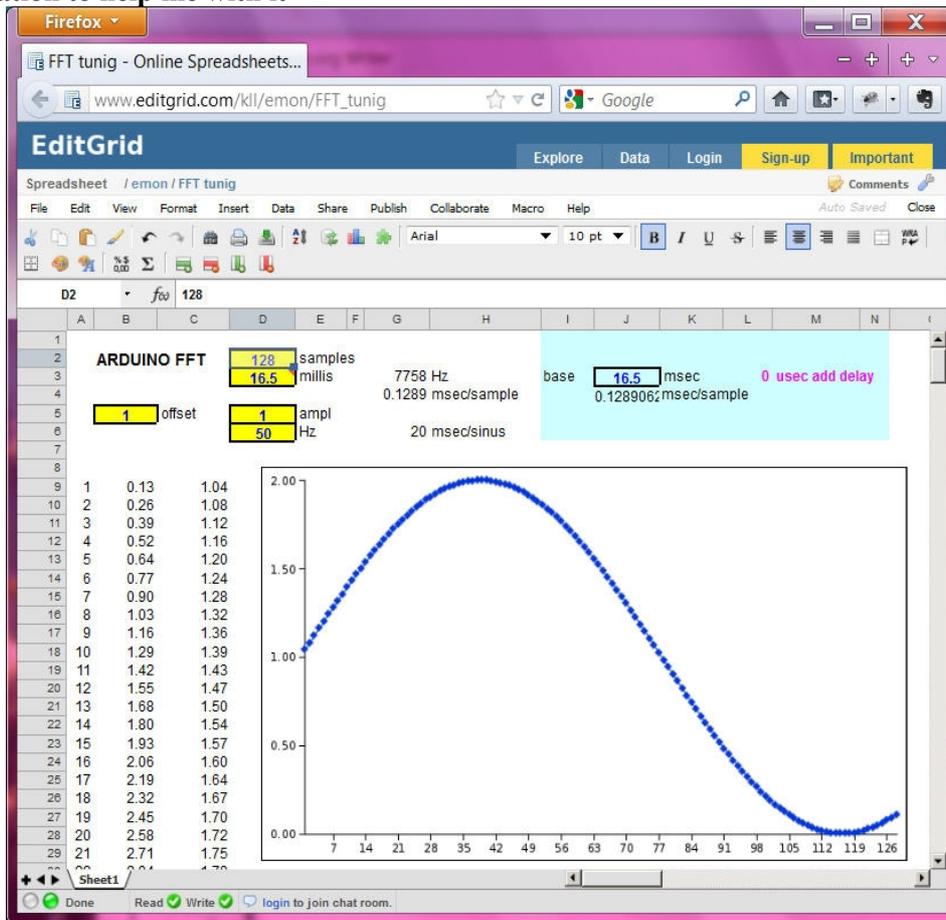
its public read write WEB 2.0 ONLINE EXCEL at editgrid.com

 **if the FFT needs 16.5 milliseconds it will not catch one 50Hz sinus (needs 20ms)
we need to slow it down to lets say 40ms == 2 sinus.
That needs a delay function of 184us at each sampling.**
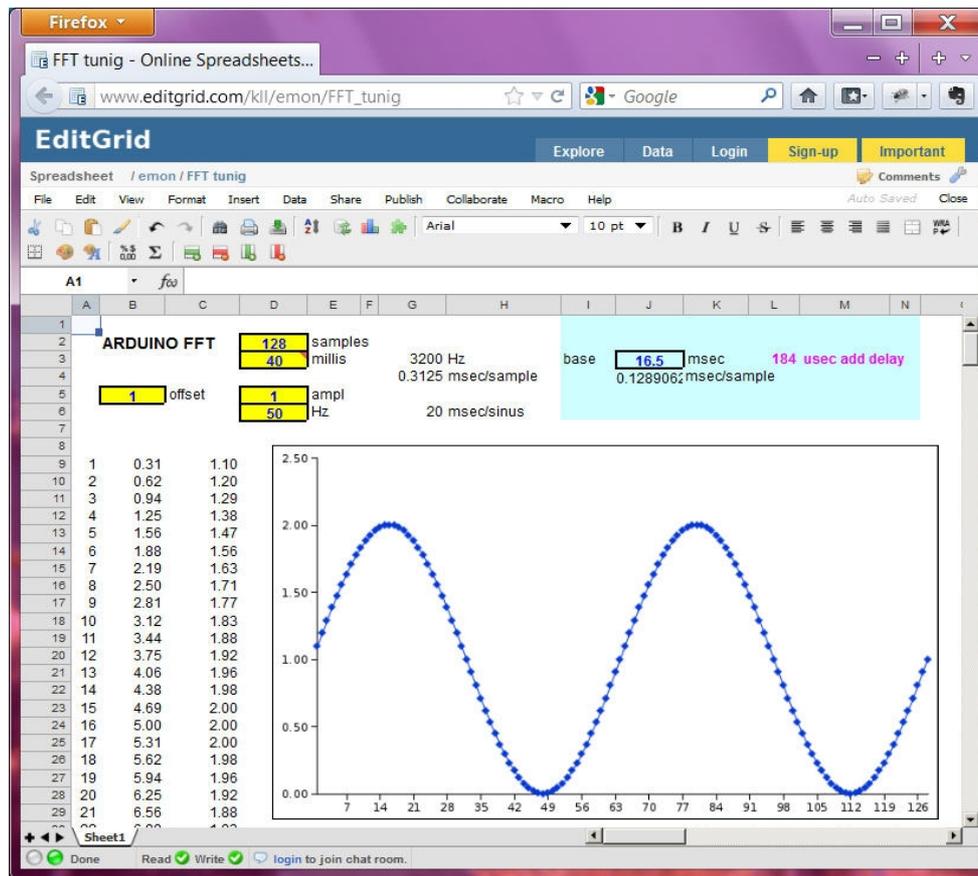
With the feature [8] you can change that default value temporary.

    –   9
Here you can change the default of EMON 3000 samples
but below 1000 the results start jumping...

so if the spec for this project was
EMON with ONLINE FFT
pls enable [1] AND [2].

for max information can use
[1] AND [2] AND [4] AND [6]
running a external terminal software and catch the datastream to a file for later analysis.

I am thinking of including SD card storage, but doubt its possible from memory.
(thats why I separated in the old projects the SCOPE version and the SD card version.)

– 5
measure A0,A1 and send to Processing

– c
select A0 or A1 for ZOOM

– z
start sample 512 values (now in a byte array only)
and send as batch to Processing for Zoom window.

UTILITIES
– a
print a ASCII list to terminal

– d
toggle diagnostic ON / OFF

– t
print loop timing of outer operation program (menu OS)

– s
show status of CONTI JOBs of that menu OS. the parallel conti job (multitasking) is not used
in that project , the menu is only used to start job batches.

If you want to check on the Source of that Arduino project,
you will find many TABs,
– **POWER_meter_FFT_v03**
– **VCC_readback**
– **ameasure**
– **common**
– **docu**
– **emon**
– **fix_fft.cpp**
– **fix_fft.h**
– **fix_fft**
– **memtest**
– **menu**
– **scopezoom**

and because of the long history of that project you see many commented lines from tests, disabled
features...

Esp. FIX FFT and EMON and VCC_readback and memtest are imported Arduino projects.
Actually I only do the scopezoom tool and pack all together in my menu tool.

On that special request I hammer in the FFT I found at ARDUINO site into the old emon + scop
project in one day,
(publish as V0.1),
and fight with the SRAM about texts, arrays, variables,
and now do the documentation and tuning later.

PROCESSING SKETCH.

When the Arduino is uploaded, all Terminals closed, the Processing application can be started.

At Processing the serial link COMxx is not in the program menu, its in the code.
After start a list of the found COMs is printed,

[0] "COM1"
[1] "COM5"
[2] "COM6"
[3] "COM13"

if communication fails you must change the sketch

 port = new Serial(this, Serial.list()[3], 115200);
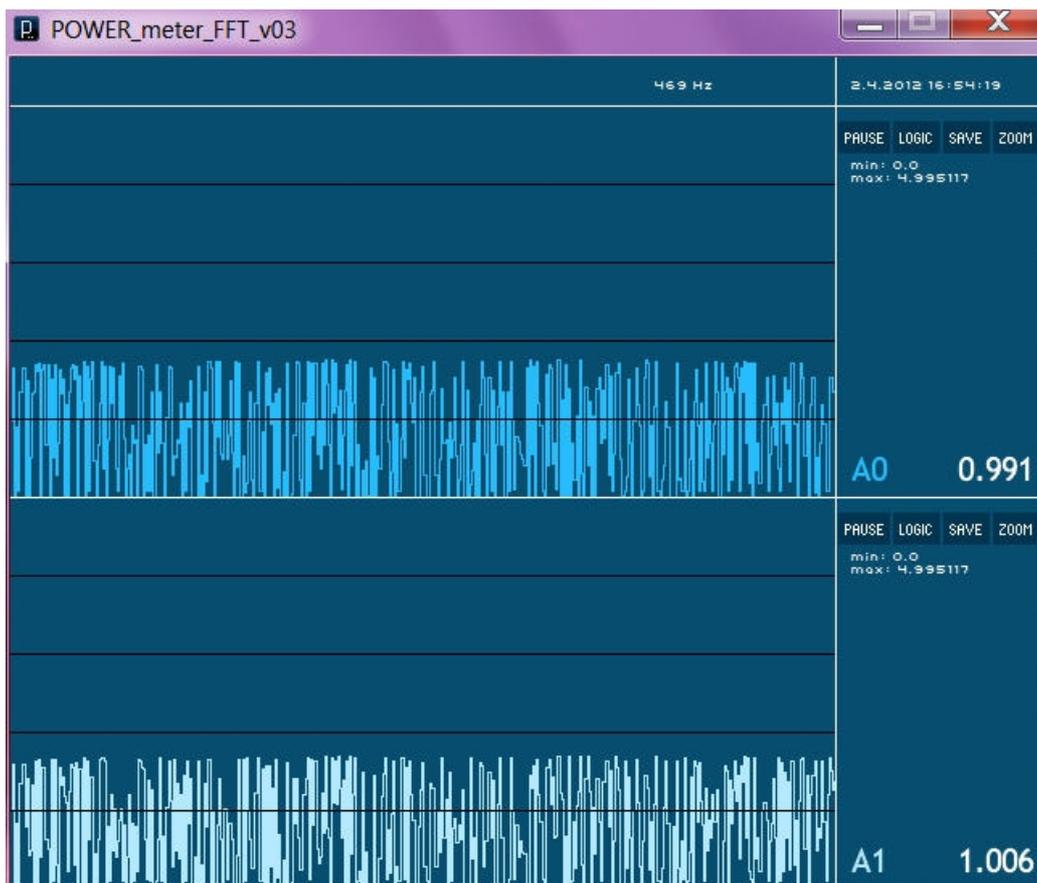
// !! if not start pls adjust serial link first.
// check in processing diagnostic window
// for the list of coms
// [0] "COM1" ....
// go line 133 and put the number what fits to com of Arduino in [xx]   / SAVE / RUN /

when it runs you see a 2 channel scope

scaling and value indication in VOLT
when you use the ZOOM button
you get a new ZOOM window (sorry the window close button not work there)
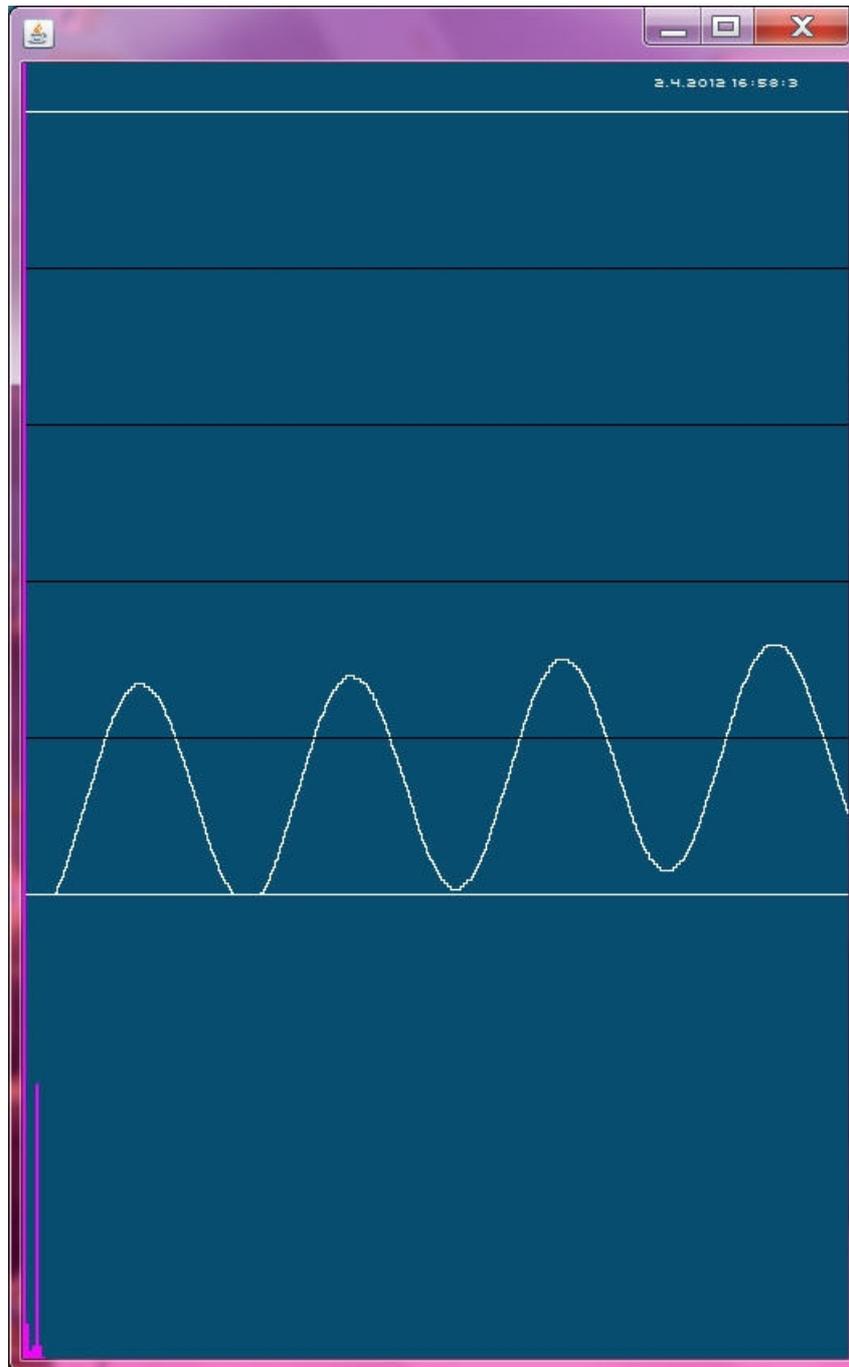
ok, now what is zoomed??
scaling is still VOLT, X is still 512 samples ,
but the timing, I switched from
- continuous 2 line ONLINE sample AND sending
(max 700Hz sample rate) to
- batch sampling 512 to array and send that batch data (OFFLINE)
to this ONE SHOT WINDOW.
(adjusted 6400Hz sample rate)

Add calculate a FFT (now on PC with the 512 samples)
show the bars in that ZOOM window,
list the first 11 FFT results in the diagnostic window of Processing,
and save the data of the ZOOM already to a CSV file.
pls note, the main window has a SAVE button (datax.csv), the ZOOM window not (any more)
because it saves automatic (Zdatax.csv).

Because its a OVERWRITE,
pls rename the file if you need to save more CSV of one channel.
There is a issue about the place where the 2 CSV types (datax, Zdatax) files are saved,
**one in Processing dir, one in sketch dir ?????**

In Processing diagnosic window pls find:

batchdata:
endbatchdata: channel: 0 millis: 77 Hz: 6649
[0] 0 Hz 884
[1] 12 Hz 30
[2] 25 Hz 13
[3] 38 Hz 16
[4] 51 Hz 180
[5] 64 Hz 16
[6] 77 Hz 10
[7] 90 Hz 7
[8] 103 Hz 7
[9] 116 Hz 4
[10] 129 Hz 4
Saved as Zdata_0.csv

the info about 512 samples in 77 millis comes from Arduino, send together with the batch
and Processing calcs with it the Hz and calibrates the FFT results.
Depending on a delay timing in Arduino we see in ZOOM about 4 SINUS
(by 512 values in 80 ms)

REMEMBER: in Arduino FFT we use 128 samples for 2 sinus, different delay timing required.

For testing at the active main processing SCOPE window you can type "T",
when you then press a zoom button arduino sends a test signal
(2 ramps UP / right is old).
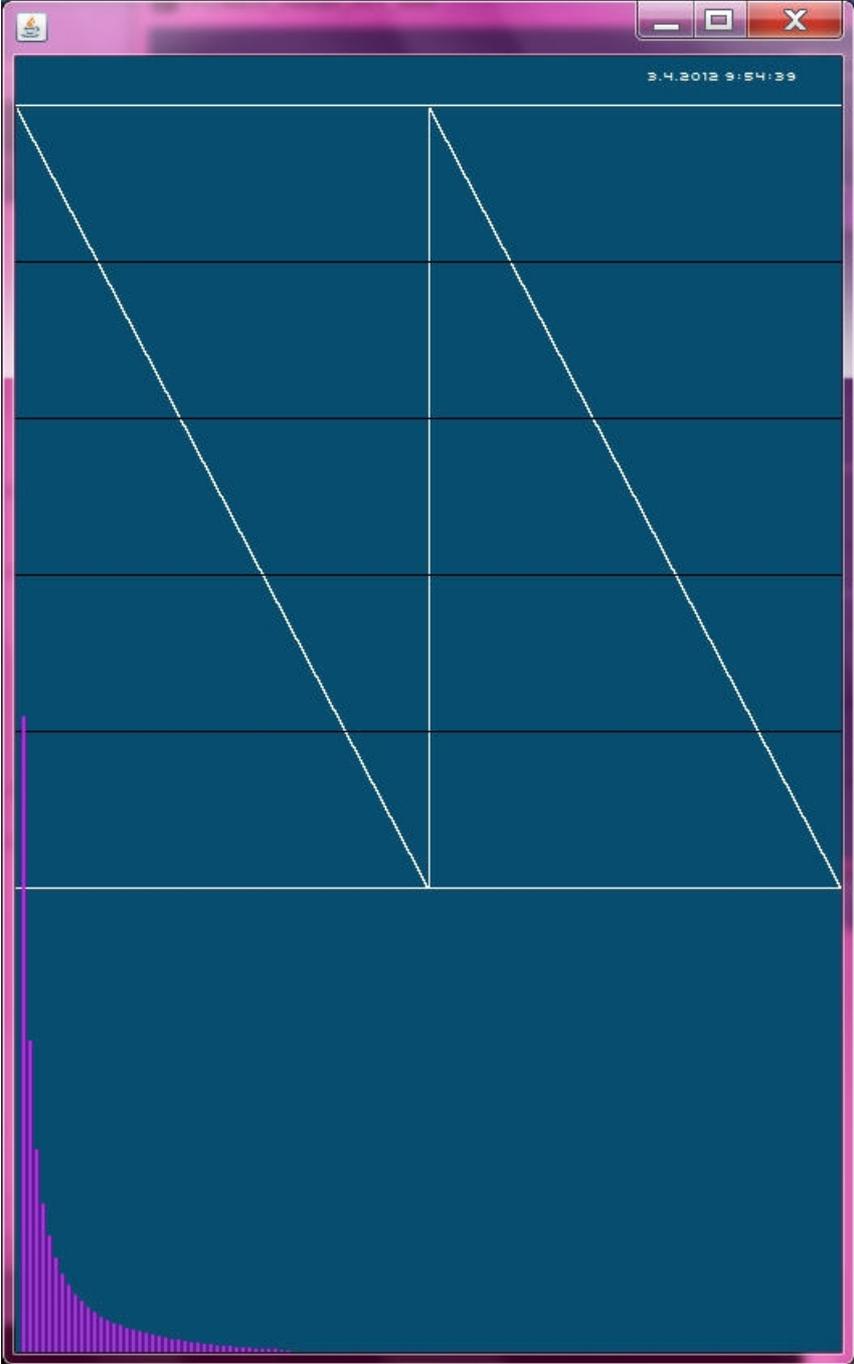
b.r. KLL

change log:
V0.1 28.3.2012 for PEDRO, requiring EMON and FFT and sample data outprint by arduino sketch

V0.2 try tuning

V0.3
major change, delete 512 int array,
increase the 2 FFT byte array from 128 to 256 and use them for 512 zoom samples too
change SCOPE to 2 channel only what allows a speedup from 100Hz to 700Hz

V0.4
EMON measure GRID frequency
FFT print list of frequencies
zoom test signal