Python Powered Scientific Instrumentation Tool

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I. ABSTRACT

Software control of data acquisition equipment allows a much finer control over events that govern an experiment. Timing tasks that are impossible to achieve manually, can be easily taken care of with a few lines of code that control hardware, and physical parameters can also be polled at precise intervals, and processed immediately in order to dictate further events. Inexpensive microcontrollers, most of which are capable of sub microsecond response times, and feature numerous communication channels, are aptly suited for deploying more sophisticated control over scientific data acquisition and control tasks. With the addition of a few peripherals such as analog gains, waveform generators etc., a microcontroller running appropriate control logic can be treated as a slave control unit that can be addressed over USB or a similar available communication pathway in order to conduct an experiment. Presenting an open-hardware, tested framework on these lines, with a peripheral set aimed at undergraduate level experiments, and an accompanying Python library for measuring parameters such as voltages, frequencies, capacitances, and time intervals, and controlling wave generators, digital outputs, current sources etc. The inputs can accommodate a wide array of sensors dealing with physical parameters such as temperature, pressure, acceleration, luminous intensity etc. Communication is taken care of by Pyserial, and graph plotting is handled by PyQtgraph[1] due its immense flexibility and speed. Since the Python program is in charge of any extracted data, its vast computational resources can be used to seamlessly extract meaningful physical data. This device is built along the lines of ExpEYES [2], but with a wider feature set.

II. STANDARD FEATURES

- Four channel,10-bit, 1MSPS oscilloscope with simultaneous sampling. Input ranges from $\pm 16V$ down to $\pm 500mV$ via analog gain control upto 32x.
- Two phase correlated sine/triangular waveform generators from 100Hz to 5KHz
- Buffered square wave and PWM outputs upto 10MHz.
- 12-bit programmable voltage sources. 0-3V, and -5V to 5V.
- 5-bit programmable constant current source upto 3.3 mA
- current to voltage convertor, with 400x gain.
- Power supply outputs. $\pm 9V$, $5V$, and high stability $3.3V$ outputs.
- Tank circuit based Inductance meter
- Frequency measurement upto 50MHz
- Two microphone amplifiers with 50x gain
- Capacitance measurement. Ranges from a few pico Farads to micro Farads.
- SPI, I2C, and UART communication channels for adding slave devices handling additional measurement and control.
- WiFi or USB communication with master PC running Python.

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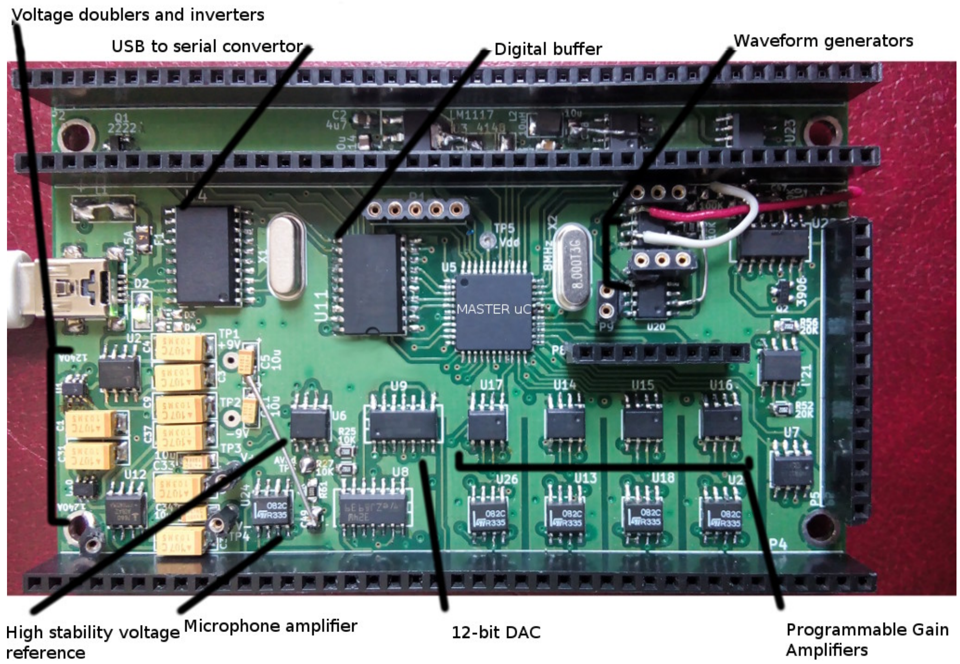

FIG. 1: Photo displaying the various parts of the device

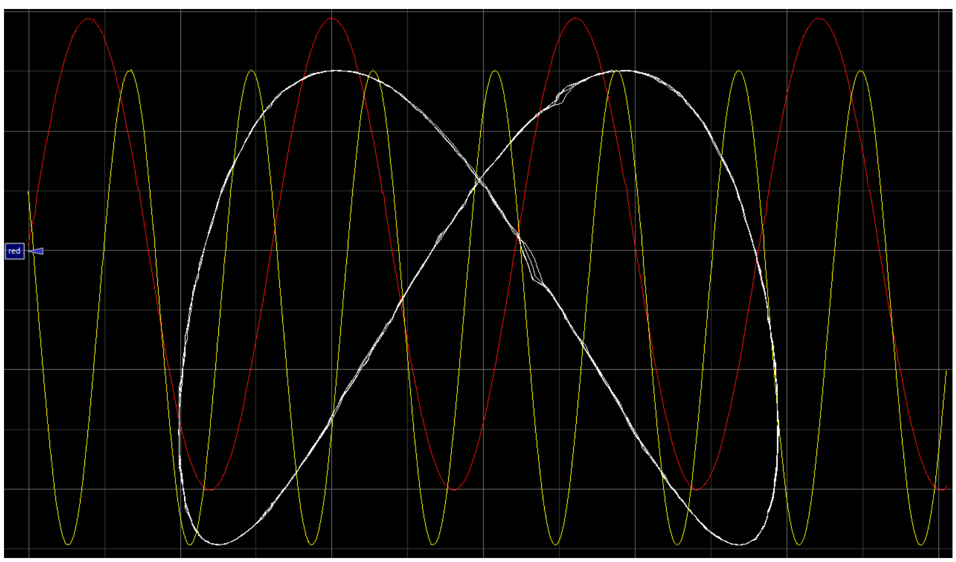

FIG. 2: captured traces from the sine wave generators(300Hz and 600Hz), and the associated Lissajous figure plotted using PyQtGraph

III. POTENTIAL APPLICATIONS

The inbuilt peripheral set has been carefully chosen in order to maximise features that are relevant to undergraduate laboratories, but with minimal extra cost. Most extra requirements can be taken care of by add-on processors which the main board can either control via the SPI/I2C/UART pathways or act as a relay between them and the PC-side Python program.

The bipolar power supplies, oscilloscopes and frequency counters are aimed at simplifying the study of fundamental circuits in electronic teaching labs. Having four monitoring channels at ones disposal allows a deeper insight, as well as faster troubleshooting. The digital inputs can function as a logic analyser and provide timing precision down to a few tens of nanoseconds.

The digital inputs are also important for time critical applications such as measuring the pulse width of the signal from a photosensor whose input light was interrupted by a high speed projectile.

The two microphone amplifiers can be used to study the propagation of sound in various media. Their output waveforms can be fitted using Numpy's toolsuite, and the calculated frequency and phase shift are a direct indication of any lags in the propagation of an audio signal.

Physical parameters obtained from sensors can be logged as a function of time.

These outline some of the ways in which such a framework can assist in carrying out experiments.

[1] http://www.pyqtgraph.org
[2] http://www.expeyes.in