Quadra Impedance Spectroscopy

Quadra provides real-time impedance spectroscopy in a compact form, well suited for embedding or autonomous field applications.

Impedance spectroscopy is a widely recognised method for examining the properties of different materials and objects in engineering, industry and biomedicine. In most applications, the impedance data is used for mapping and correlation with a phenomenon of interest. The measurement is relative by nature, focusing on a change or comparison with a baseline, rather than determining the value of impedance on an absolute scale.

Quadra has been designed to perform impedance spectroscopy in real time – the novel technology (Figure 1) allows it to acquire a spectrogram of 15 frequencies during a short time frame of 1 ms. Therefore, it is best suited for applications where the measurement time is limited or the phenomenon of interest is changing rapidly. High repeatability of the measurement and sufficient number of frequency points on the spectrogram facilitate accurate characterisation of objects or systems under investigation.

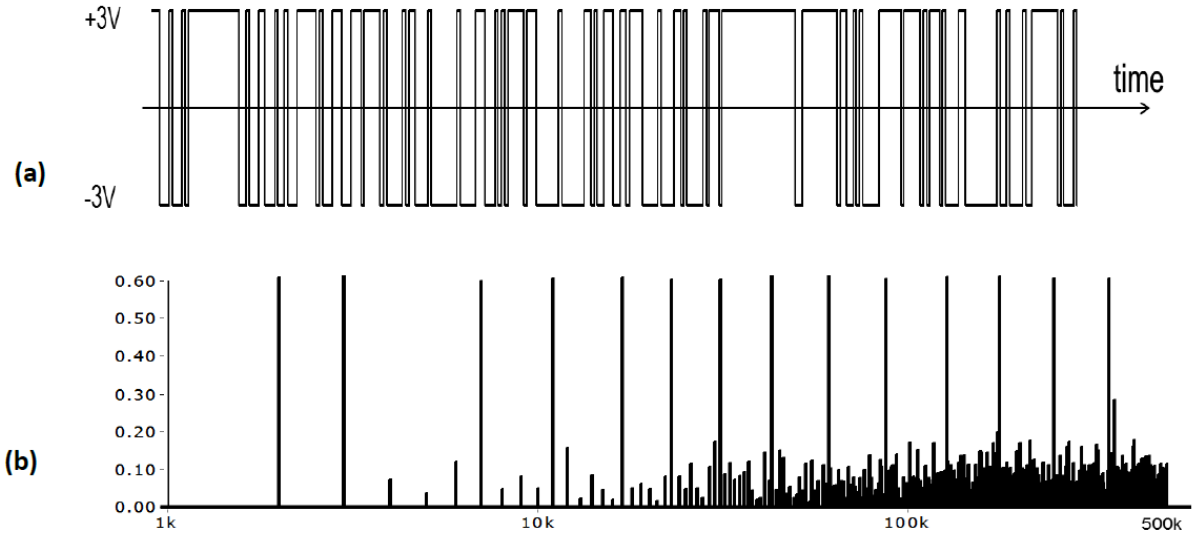

Figure 1 Example of a spectrally sparse multi-frequency binary waveform (a) with known spectral content (b), which is used as excitation signal.

Elements of the Quadra platform

Quadra impedance spectroscopy platform consists of an application specific front-end and the DSP (Digital Signal Processing) module, which streams measured data to the host system for further processing. The platform can be implemented as modules – in separate enclosure(s) or integrated into host system enclosure. The front-end and DSP circuits can also be embedded in a custom PCB design.

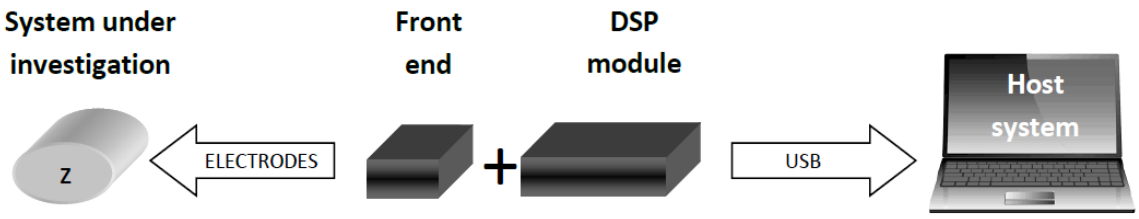

Figure 2 Quadra platform implementation with stand-alone modules and host PC.

DSP module

The DSP module provides generation of binary waveform and real-time calculation of impedance or admittance. Different sets of 15 frequencies can be selected. The highest set, 1 kHz to 349 kHz, enables 1 ms acquisition time and covers a wide range of applications from tissue and material structure mapping to detection of cells and coatings. The lowest set, 0.5 Hz to 195 Hz (acquisition time 2 s), extends down to frequencies used for e.g. electrochemical applications.

The DSP module can be powered by an internal battery, useful feature for e.g. biomedical applications where a mains power supply cannot be used due to safety reasons. The USB data signals are internally galvanically isolated and by switching to the battery power complete galvanic isolation between Quadra and host PC is achieved. This helps to reduce noise and parasitic excitation current leakage. The battery in the stand-alone enclosure can be charged via USB, which also serves as the standard communication interface.

Application specific front-end

Each application requires specific electrode arrangement for excitation and response measurement. The front-end connects to the electrodes and provides signal conditioning for DSP module. In stand-alone applications, standardised SubD25 connector on the DSP module allows to prepare different setups and quickly switch from one measurement to another.

All applicable combinations of voltage and current for excitation/monitoring in 2- or 4-wire configuration can be implemented by appropriate front-end design. Customised designs are available on request.

Data processing in the host system

Data processing in the host system enables visualisation and extraction of useful information. Windows GUI (Graphical User Interface) is used to control the main functions of Quadra device and to display or log the measurement data. LabVIEW and Matlab toolboxes with same functionalities are also included.

Control and data processing support is available as optional services.

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Quadra evaluation kit:

- Quadra DSP module;
- Front-end with voltage excitation and 1 kΩ current measurement shunt;
- Software (Windows GUI; LabVIEW and Matlab toolboxes) for operating Quadra as well as data acquisition and visualisation;
- Impedance demo board for setup verification.

Technical parameters of the DSP module

Parameter	Value
Impedance	Relative value of impedance (module in Ohms and phase in degrees)
Measurement repeatability	0.1 %
Spectrogram acquisition period	1 ms
Number of frequencies in spectrogram	15
Spectrogram frequency range	1 kHz to 349 kHz (highest set of frequencies), sets of lower frequencies from 0.5 Hz to 195 Hz range available
Excitation waveform	Spectrally sparse signal, contains set of 15 predetermined frequency components
Excitation channel	1 differential output (50 Ω), bipolar output voltage range 0.2 Vpp to 3.8 Vpp (selectable in 255 steps, DC offset 0 V)
Measurement channel	2 differential channels (input resistance >10 MΩ), bipolar input voltage range 3 Vpp at preamplifier gain 1x (selectable gain values 1x, 2x, 5x, 10x)
Host interface	12 Mbps, Full Speed, USB 1.0, USB 2.0, USB 3.0, (PC computer with Microsoft Windows 7 and above)
Power	USB bus: 500 mA (2.5 VA), or internal battery (8 h autonomous operation)
Module dimensions	(110 × 60 × 20) mm
Space required for DSP embedding	Less than (30 × 30) mm of PCB area

Description of available front-end designs

Type	Description
Single shunt	Uses a voltage divider method for impedance measurement. Voltage on the SUT is measured directly and the excitation current is measured as a voltage drop on the known reference impedance that also acts as a current limiter. A 1 kΩ precision resistor is used as the reference impedance by default. The shunt value is customisable and it should be similar to the measured impedance for obtaining best measurement accuracy.
Multiple shunt	A version of single shunt front-end that allows automatic switching between up to eight different reference impedances. Parallel connection of the references is also possible. The number of resistors and their values are customisable.
Biologically safe	Designed to fulfil the safety requirements posed by IEC60601-1 standard like current limiting and first fault tolerance. The use of this front-end does not make Quadra a medical device but assures that no harm can be done to biological targets.
Transimpedance	Uses voltage excitation directly from positive terminal of Quadra differential 50 Ω output. The voltage drop is measured across the object and the current flowing through the object is measured using transimpedance amplifier. This measurement topology provides low impedance connections for the excitation current and is less susceptible to noise and interferences in the measurement environment. Care must be taken in setting the amplitude of the excitation voltage in order not to cause too high excitation current.
Current source	Uses a current source topology for generating excitation current. The voltage is measured directly across the object and the current flowing through the object is measured using transimpedance amplifier. The measurement current does not depend on the measured impedance.
Multiplexer	Uses analog cross-point switch and allows any of the excitation signals and sense signals to be connected to any of the configurable output pins. Versions with 12 and 16 output pins are available. Measurement time for one multiplexer output configuration is up to 4 ms.
Breakout	Adapter board for providing easy access to the pins of Quadra measurement connector (SubD25) for users who want to prototype their own front-end circuitry.
Custom	Specifically designed to meet your technical needs.

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