Biosensors

B. Tech.

Course No.: EEL 3050

L-T-P [C]: 3–0–2 [4]

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ELECTRICAL ENGINEERING

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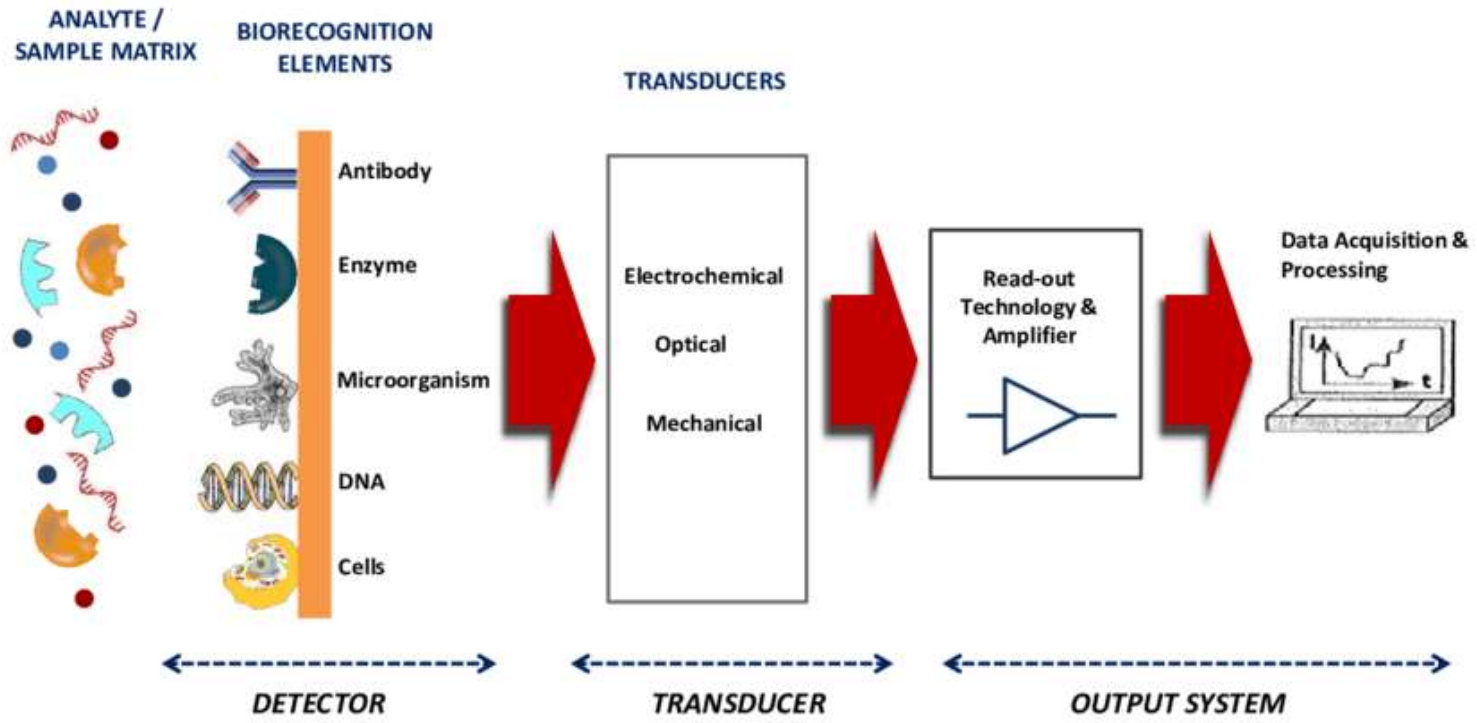
Lecture 33 dated 11th Nov. 2024

Readout electronics for biosensors:



Schematic diagram of biosensor comprising three components: detector, transducer and output system.

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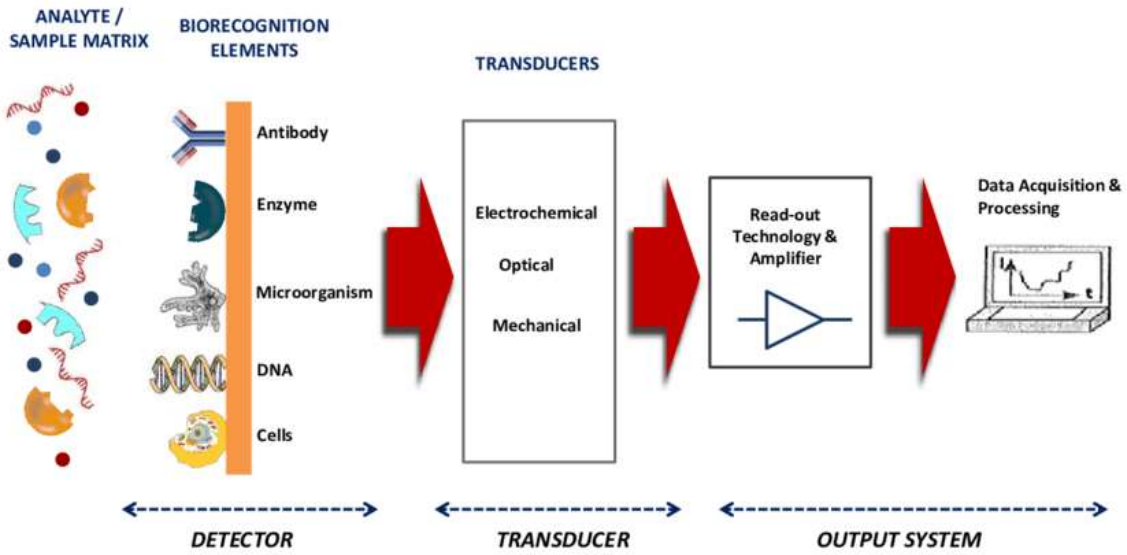

Schematic diagram of biosensor comprising three components: detector, transducer and output system.

A biosensor typically consists of

- a bio-receptor (enzyme/antibody/ cell/ nucleic acid/ aptamer),
- transducer component (semi-conducting material/ nanomaterial), and
- electronic system includes a signal amplifier, processor & display.
- Transducers & electronics can be combined, e.g., in CMOS-based microsensor systems.

Readout electronics for biosensors :

- **Readout electronics** are signal-conditioning circuits that convert changes in a sensor's capacitance, inductance, or resistance into measurable voltage or current quantities.
- They are important for developing low-cost, low-power, and reliable sensor systems.

The electronics can include:

- Amplification: The electronics to amplify the signal.
- Conversion: The electronics to convert the signal from analog to digital.
- Signal conditioning: The electronics to perform signal conditioning.
- Data acquisition: The electronics to acquire data in real-time.
- Data processing: The electronics to process the data.

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Some components of readout electronics include:

- **Trans-impedance amplifier**: Has automatic gain adjustment
- **Filter stages**: Part of the readout circuit
- **Magnitude and phase detection circuit**: Part of the readout circuit
- **Analog-to-digital converter (ADC)**: Converts analog video signals into digital samples
- **Video amplifier**: Combines multiple functions of analog signal processing
- **Repeating patterns:** The sequencer can generate a flexible structure for repeating patterns like frames, lines, or pixels
- **Analog filtering:** Includes a moving average filter to reduce noise in the signal

Readout electronics requirements:

Low-power consumption

- Readout electronics can help develop **low-power sensor systems**.
- Ex., one readout circuit was designed to **consume 571 µW**, which is **lower than** other readout circuits based on **organic electronics**.

Noise immunity

- Readout electronics can help **achieve noise immunity**.
- Ex., one readout circuit was designed to include an analog filter to reduce noise in the signal.

Linearity

- Readout electronics can help achieve linearity.
- Ex., one readout circuit was designed to have a high linearity for sinusoidal signals.

Readout electronics requirements:

Low-complexity

- Readout electronics can help achieve low-complexity.

Minimum sensitivity to mismatch

- Readout electronics can help minimize sensitivity to mismatch.
- Ex., one readout circuit was designed to include a feedback system to increase linearity and minimize the effect of mismatch.

Display Unit:

- The **display unit** of the biosensor quantifies the processed signals.
- The display can be a liquid crystal display or a printer that generates **numbers** or **curves**.
- The output signal can be numeric, graphic, tabular, or an image.

Some ideal characteristics for capacitive biosensors are:

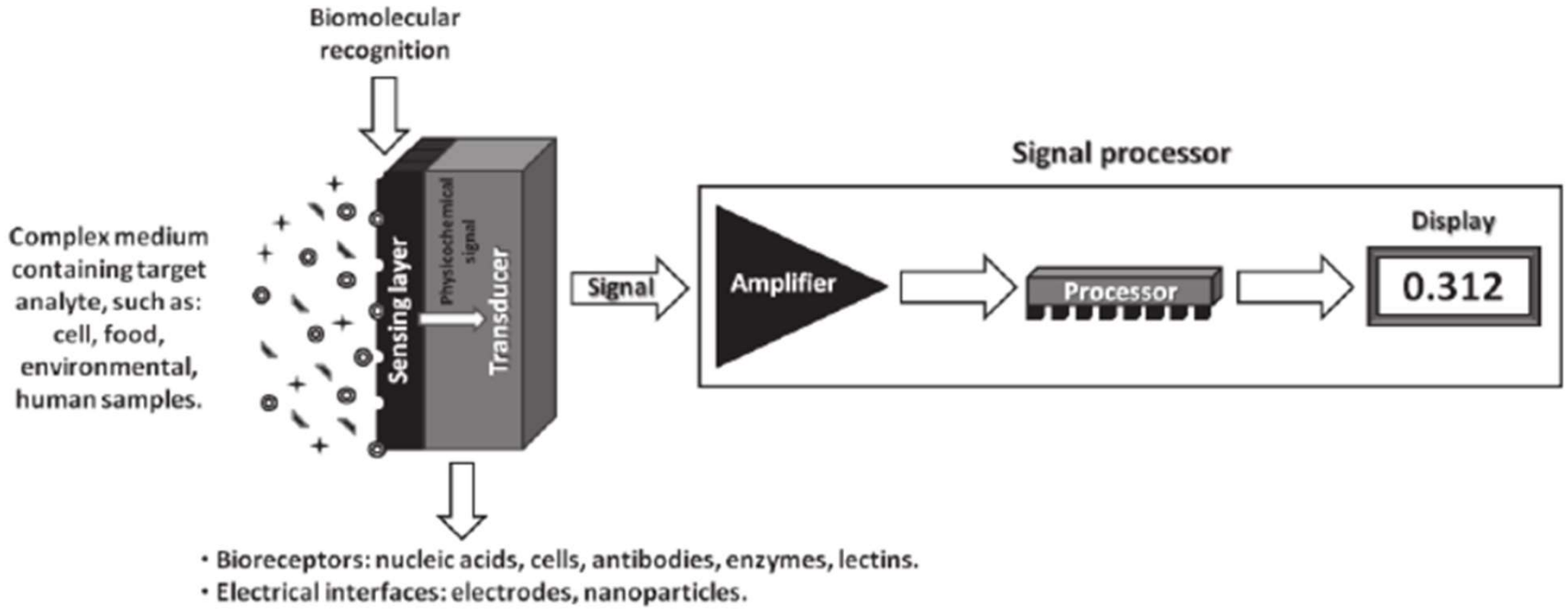
- Low-power consumption
- High-resolution
- Linearity
- Noise immunity
- Minimum complexity
- Less sensitivity to the mismatch in CMOS technology

Some definitions:

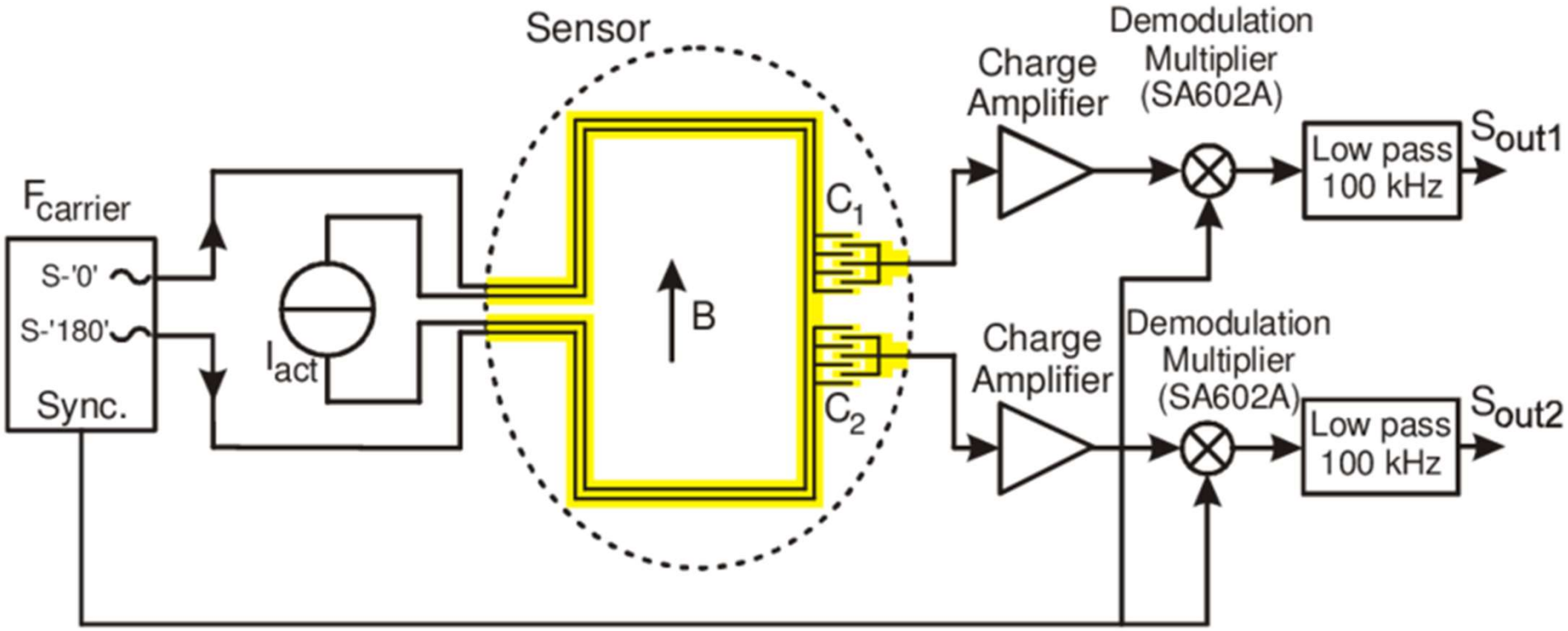
- A potentiostat is an electronic device that measures and controls the potential (or voltage) difference between two electrodes
- Amperometric circuit measure the current flow between electrodes when a redox reaction takes place.
- Charge converters and charge amplifiers transform charge output signals with high-impedance to low-impedance voltage or current.
- Variable gain amplifiers (VGAs) are signal-conditioning amplifiers with electronically settable voltage gain.
- A low-noise amplifier (LNA) is commonly found in all receivers. Its role is to boost the received signal a sufficient level above the noise floor so that it can be used for additional processing.

Some other considerations while designing a readout unit for a biosensor include:

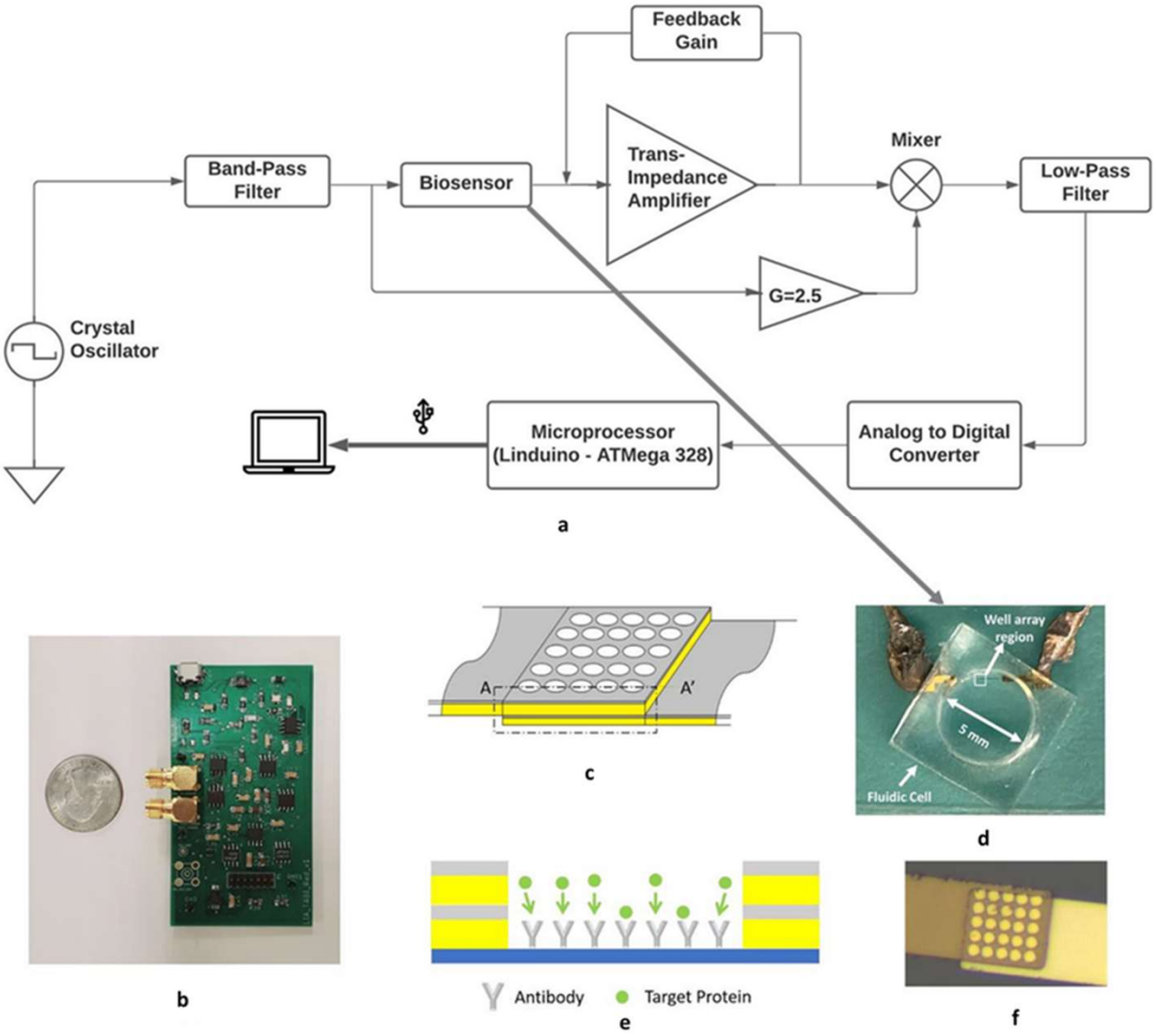
- **Signal-to-noise ratio (SNR)**: The SNR is an important design parameter.
- **Common-mode-to-differential conversion** (CM-to-DM): This is another important design parameter. CM-to-DM conversion is the process of **changing** a common signal into a differential signal. It can be caused by imbalances in the termination networks.
- **Digitization configuration/speed**: This is another important design parameter.
- **Data processing method**: This is another important design parameter.



Schematic diagram of a biosensor that is **consists** of a bioreceptor for the **specific detection** of the respective analyte in spatial contact to a transducer for **converting** the **signal into an electrically manageable format** and a signal processing unit.



Schematic diagram of the **actuation** and **readout** electronics.



(a) System diagram of the Portable Electronic Readout System (b) Pic of a lock-in amplifier on a PCB with onboard ADC (80 mm × 43.6 mm) (c) Schematic Nanowell Array Impedance Sensor (d) Pic of a nanowell array impedance sensor. (e) Principle of nanowell array impedance sensor: the **antibodies** & **target** proteins occlude the current path & result in an increase in the impedance (f) Microscopic picture of the 5 × 5 nanowell array.

A Capacitive Readout Circuit for a Disposable Low-Cost Pressure and Flow Sensor with 200 Pa or 170 nl/s Resolution

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Presented at the IEEE SENSORS 2019 conference

27-30 October 2019, Montreal, Canada

IEEE Sensors Council

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Questions??