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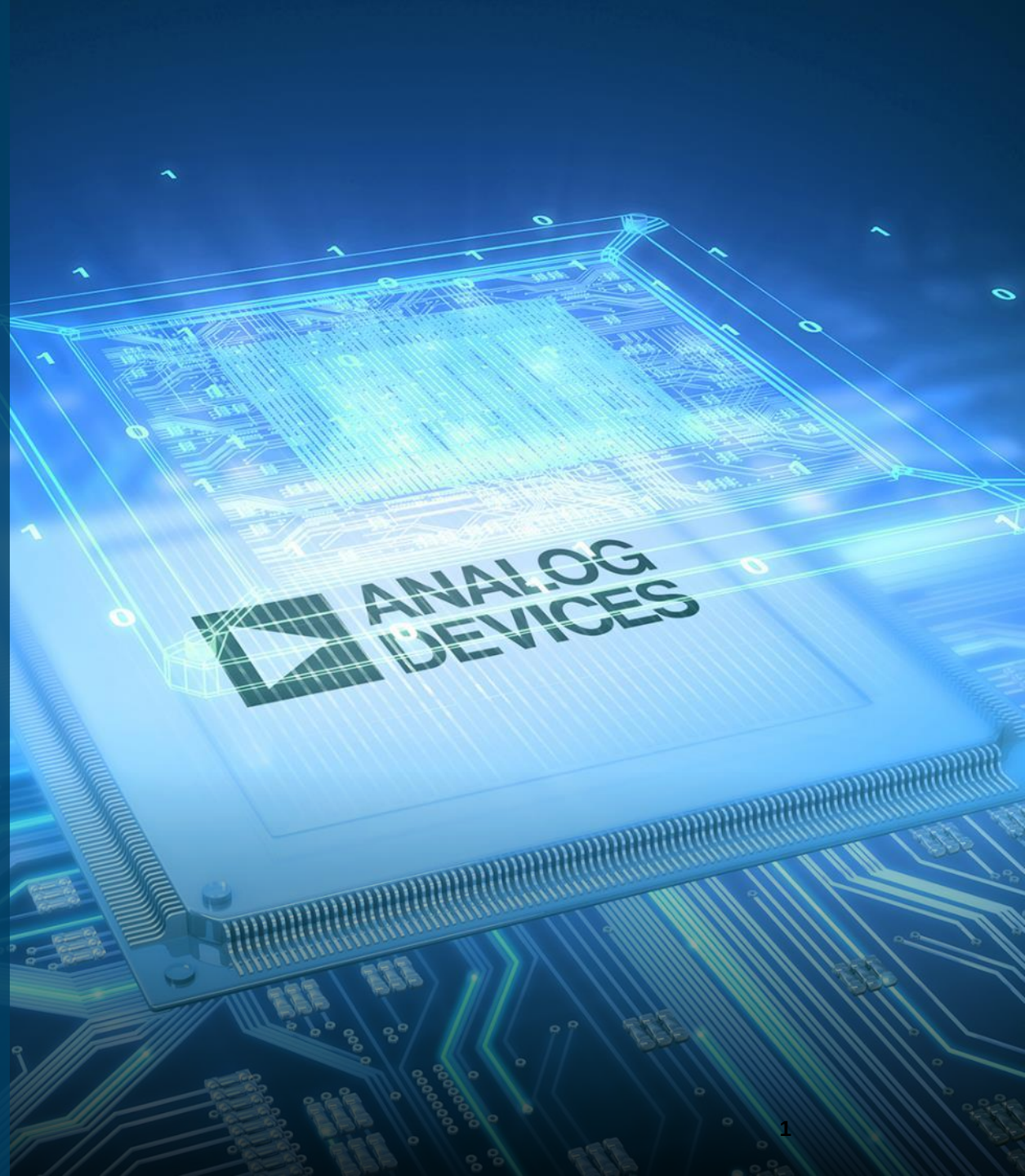
Technologies for Wearable and Clinical Vital Signs Monitoring

JAN-HEIN BROEDERS

Healthcare Business Development Manager EMEA



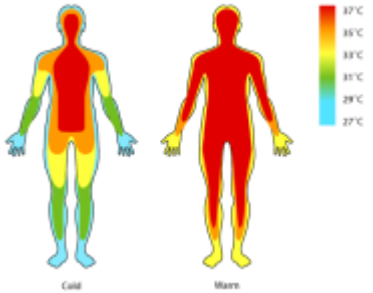
05/17/2018

Agenda

- Introduction to Vital Signs Monitoring
- Technologies for Wearable VSM
- VSM Use-cases
  - Bio-Potential Measurement
    - ECG & Heart Rate Monitoring
  - PPG / Optical Measurement
    - Optical Signal Chain
    - Discrete vs Integrated Modules
    - HRM/HRV and SpO2
  - Bio-Impedance Measurement
    - Electro Dermal Activity (EDA)
    - Body Impedance Analyses (BIA)
  - Motion Sensing
- Wrap Up

Why Measure Vital Signs?

- Primary Vital Signs are
  - Heart Rate [50-80BPM]
  - Blood Pressure [120/80]
  - Temperature [37-38C]
  - Respiration [12-20Breaths/m]



- Vital Signs are measured to observe the condition of a person
- Numbers need to be within a certain ranges (ranges are age dependent)
- VS can help the Physician to make the right diagnoses
- VS are measured while giving medication and treatment to monitor the (desired) effect
- More awareness for Personal Health Condition

Trends in Measuring Vital Parameters

Clinical VSM

High Performance
FDA / CE Approved
Focused at Patients
Hospital Operated

ECG
SpO2
CO2
Resp Rate
Temp
Blood Press.

Telemetry

High Performance
FDA / CE Approved
Focused at Patients
Hospital / Home Operated

ECG
SpO2

Sports & Wellness

Low Performance
Un-regulated
Personal Interest

HRM
Step Count
Motion Profile
Skin Temp.
EDA

In Hospital

Out Hospital

Wearable VSM

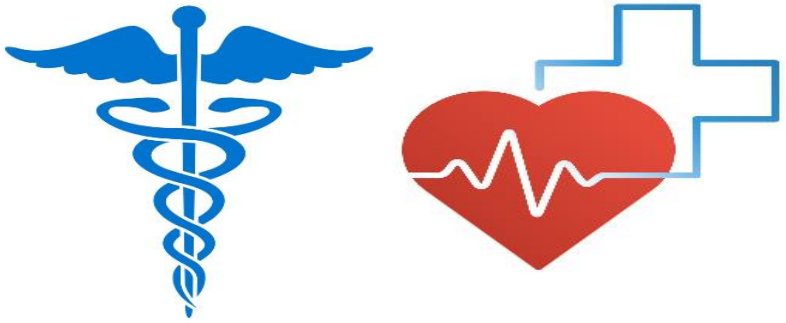
Professional / Semi-Prof Market

Remote Monitoring
Some regulation

ECG, HRM, Resp Rate, SpO2,
EDA, Motion, Temperature

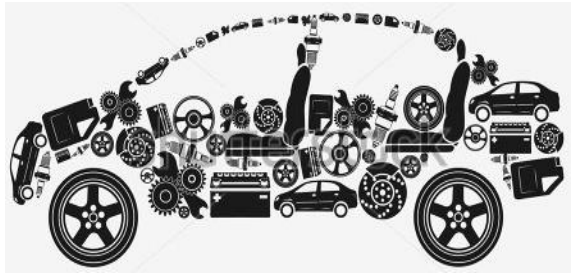
VSM Opportunities are Everywhere

Medical



Home - Sport & Wellness

Automotive - Military



Security

Assisted Living

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Required Technologies for Wearable VSM

Level of Activity

MEMs Motion Sensing

Body Comp.

Impedance Measurement

Stress Level

Impedance / Optical Measurement

Vital Signs

Optical / Bio-Impedance / Bio-Potential

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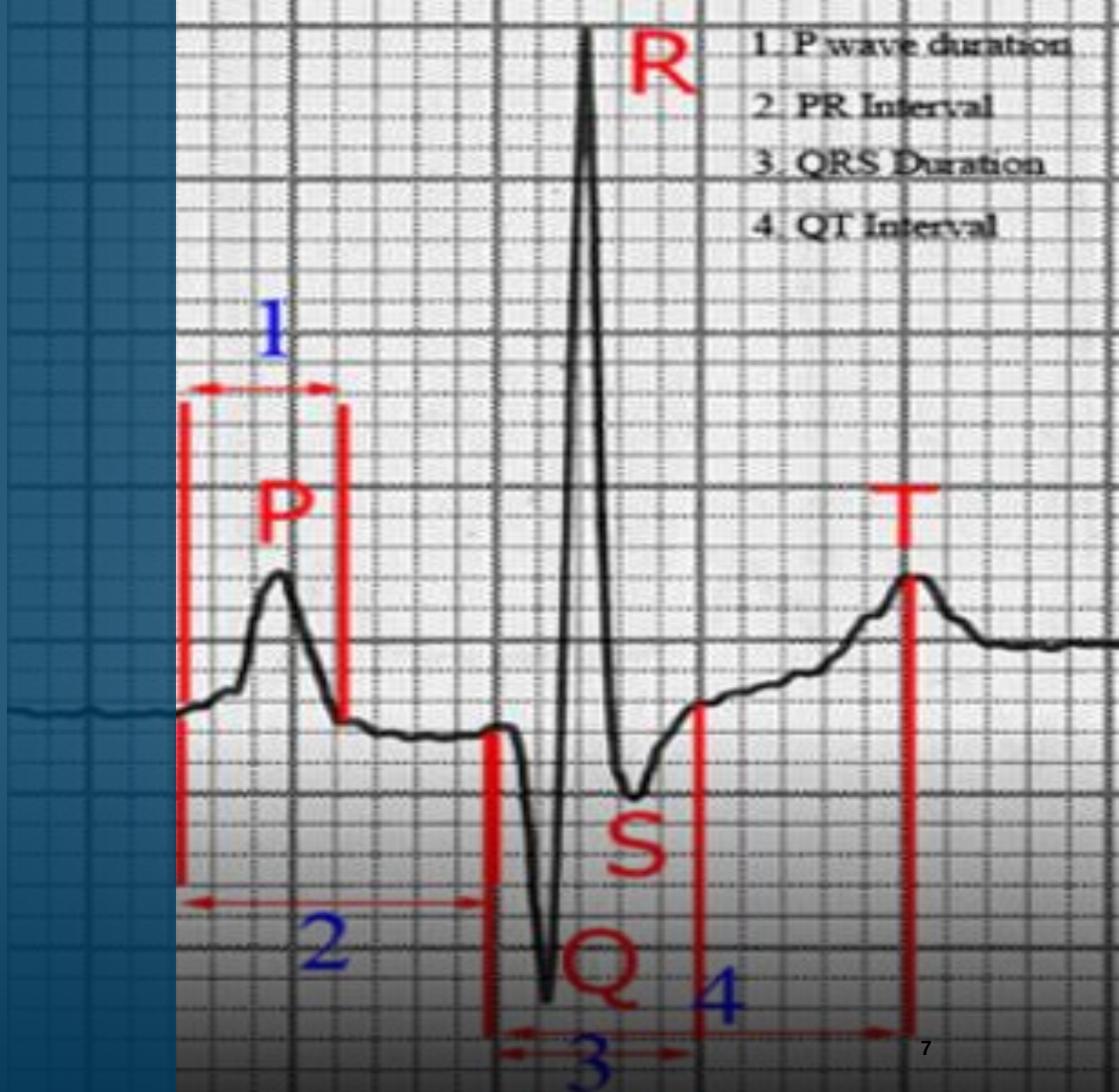
Bio-Potential Measurement



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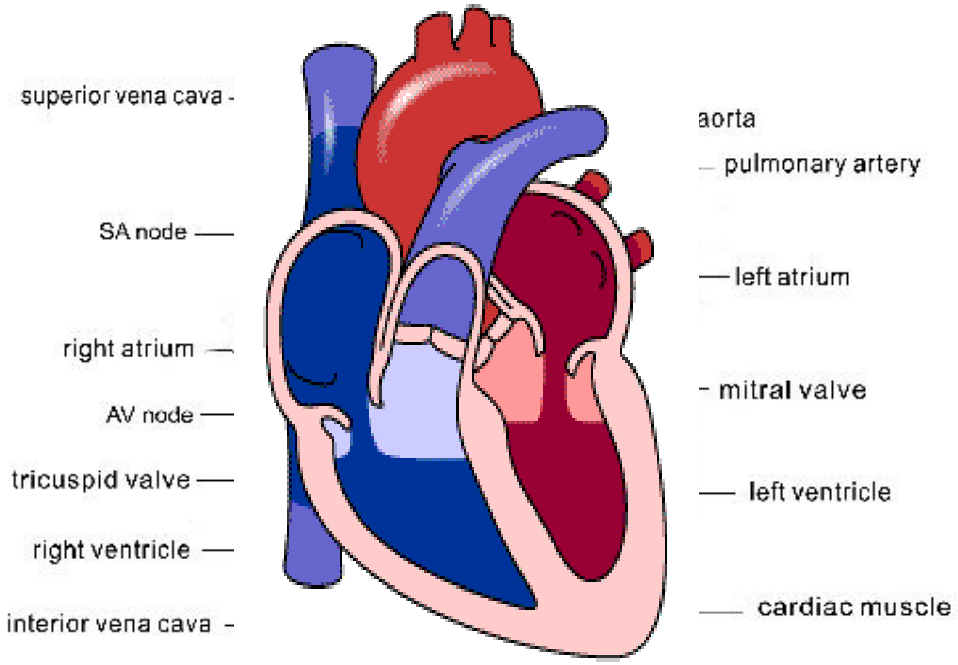
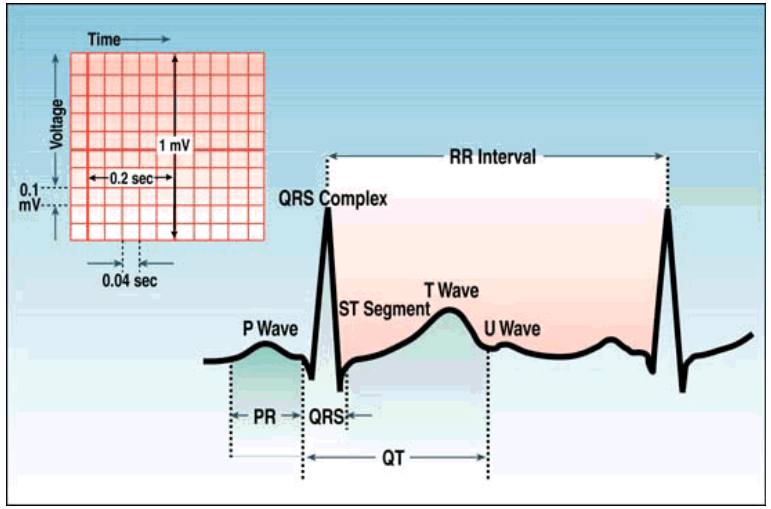
Bio-Potential Measurements

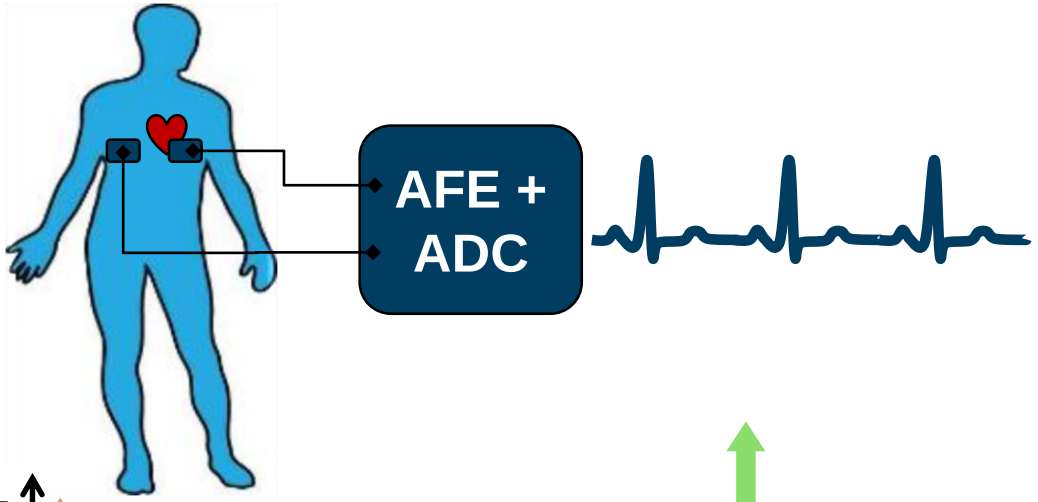


Cycle of one Heart Beat

- **P-Wave : Atrium Compression**
- **QRS : Ventricle Activation**
- **T-wave : Settling Activity**



Signals and Interferers



Main Electrical Requirements	
Bandwidth	0.05-150 Hz
Amplitude	1-10mV$_{pkpk}$
Noise RTI	10µV$_{pkpk}$
Differential Input Voltage Range	±1V

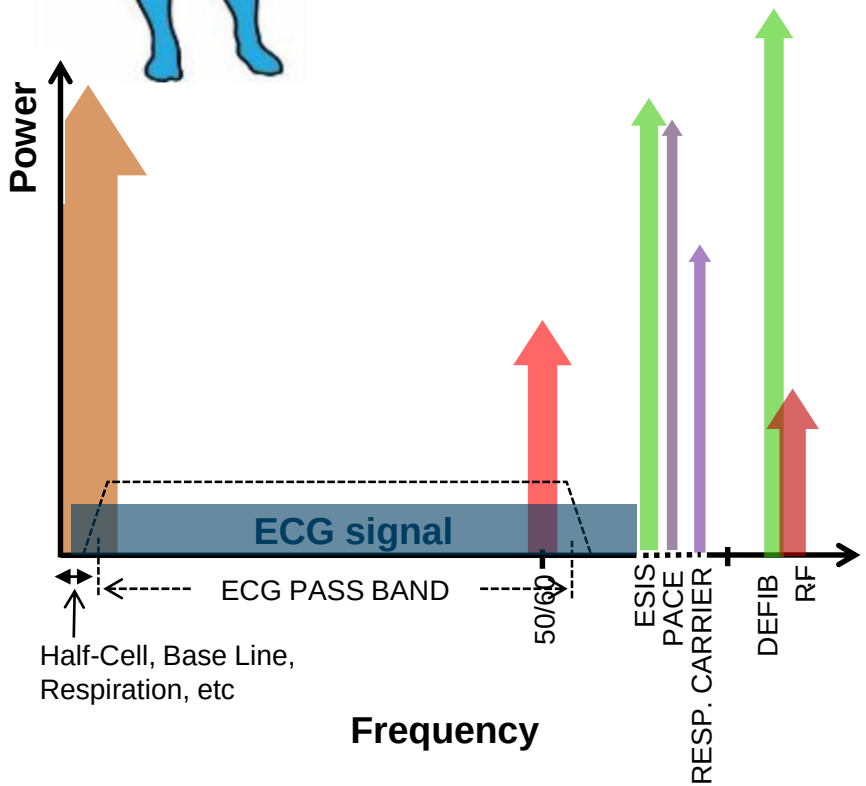
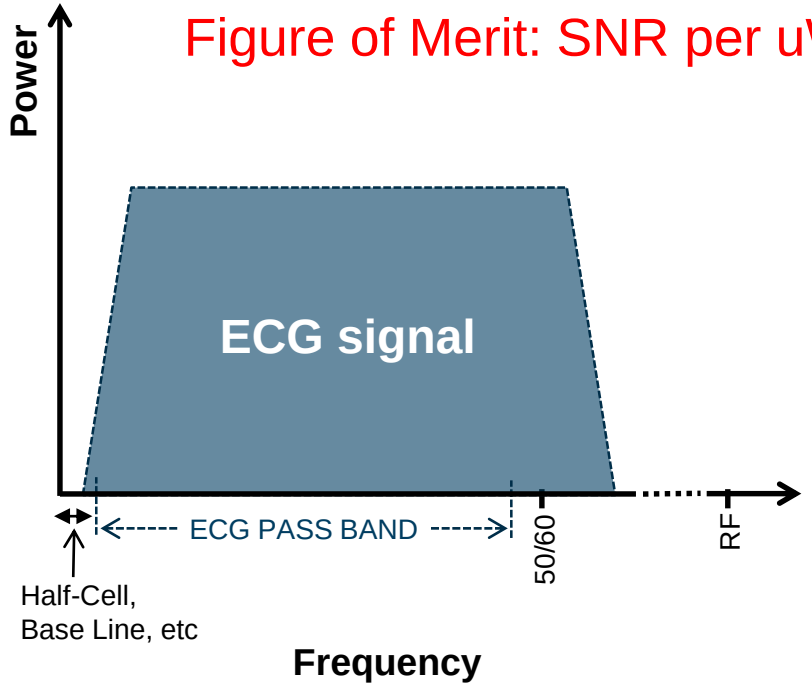


Figure of Merit: SNR per uW



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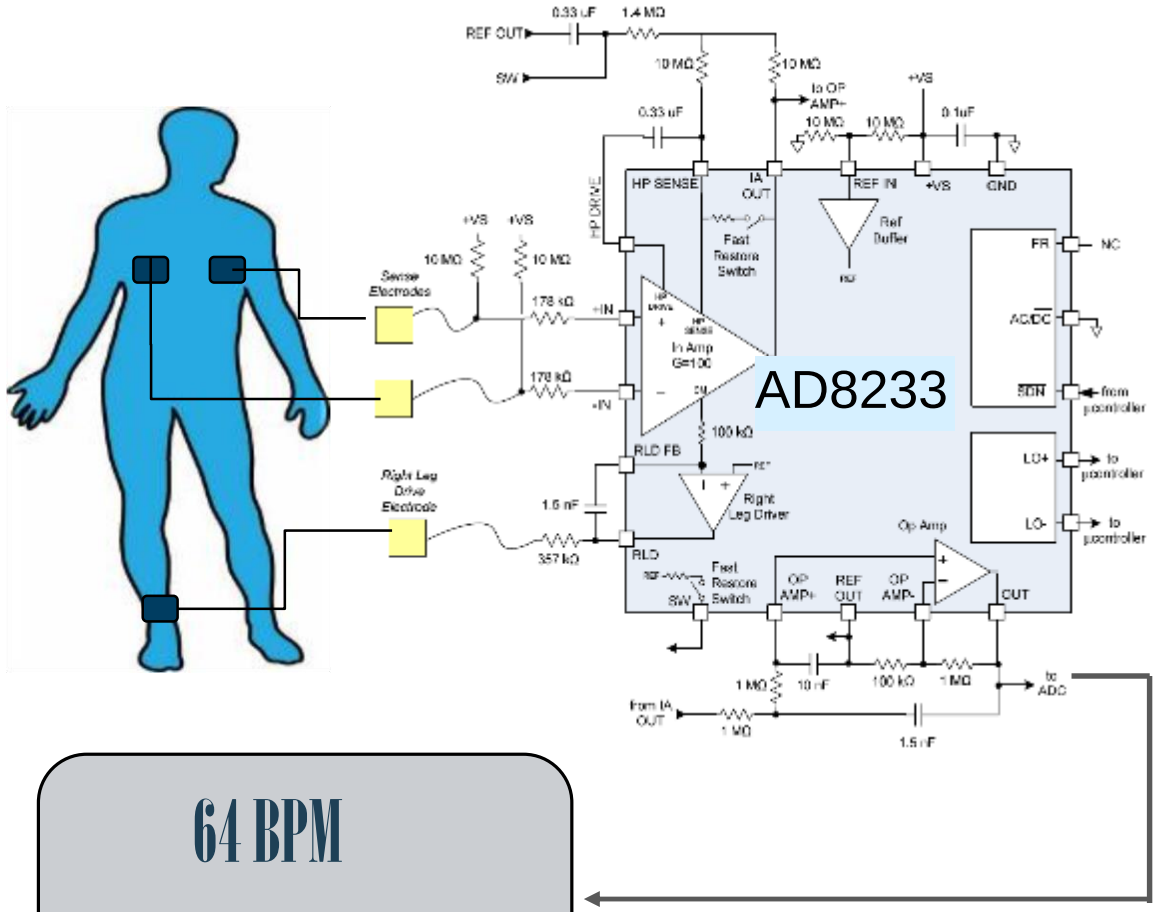
AD8233 – Ultra Low Power Single Lead ECG Front-End

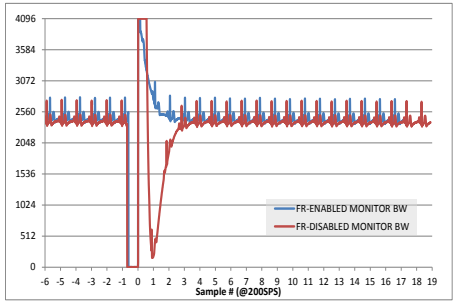


64 BPM

ADUCM3029

Features

- Two-Pole High Pass Filter
  - Electrode DC offset removal
  - Selectable Cutoff Frequency (0.05 to 10Hz)
- 3rd Order Low Pass Filter
- Integrated Fast Recovery Circuit (FR)
- AC and DC Leads Off Detect
- Integrated Right Leg Drive (RLD)
- Operates on 1.7 to 3.5V (direct from Battery, no regulator needed)
  - 50µA normal mode
  - <1uA shutdown mode
- Tiny 2mm x 1.7 mm WLCSP



Target Applications

- Fitness and Activity Heart Rate Monitoring
- Portable, Remote and Home ECG systems
- Any Low End Cardiac System

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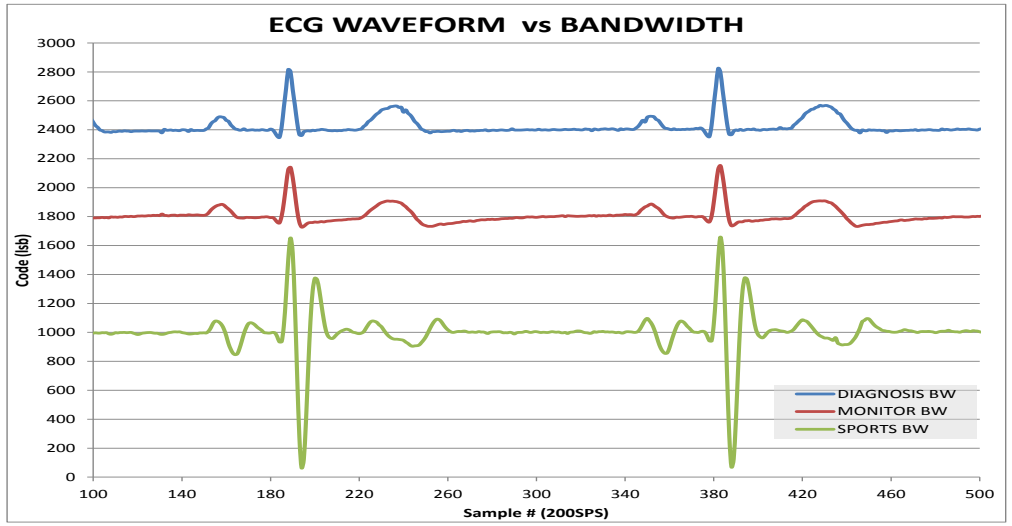
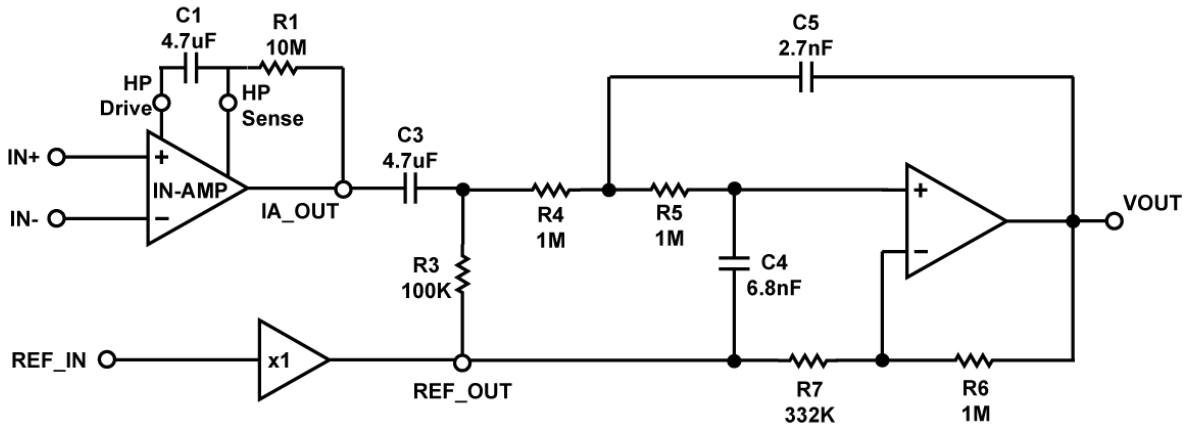
Passing Bandwidth vs Time Response



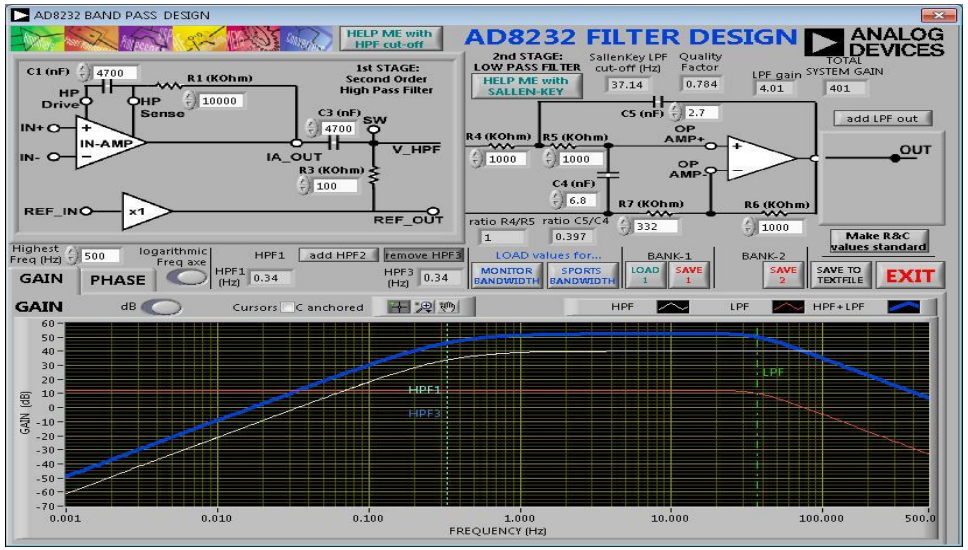


- Band of interest depending of use-case :

SPORTS (7-25Hz)

MONITOR (0.5-40Hz)

DIAGNOSIS (0.05-150Hz)



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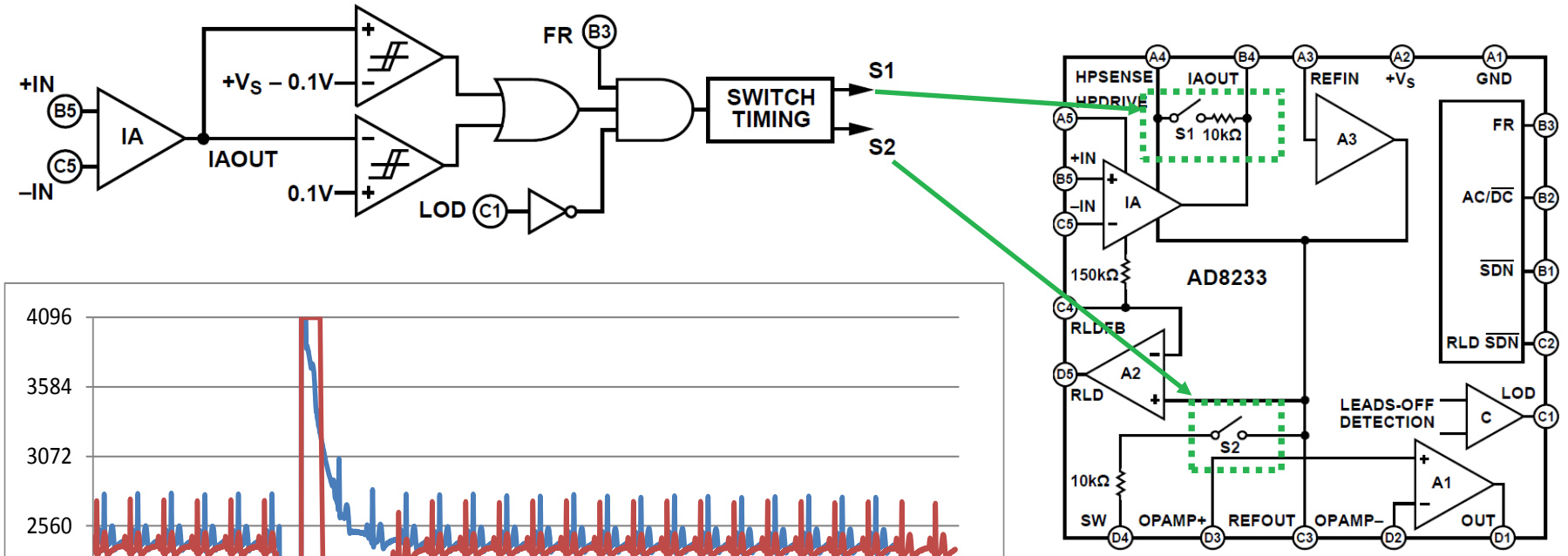
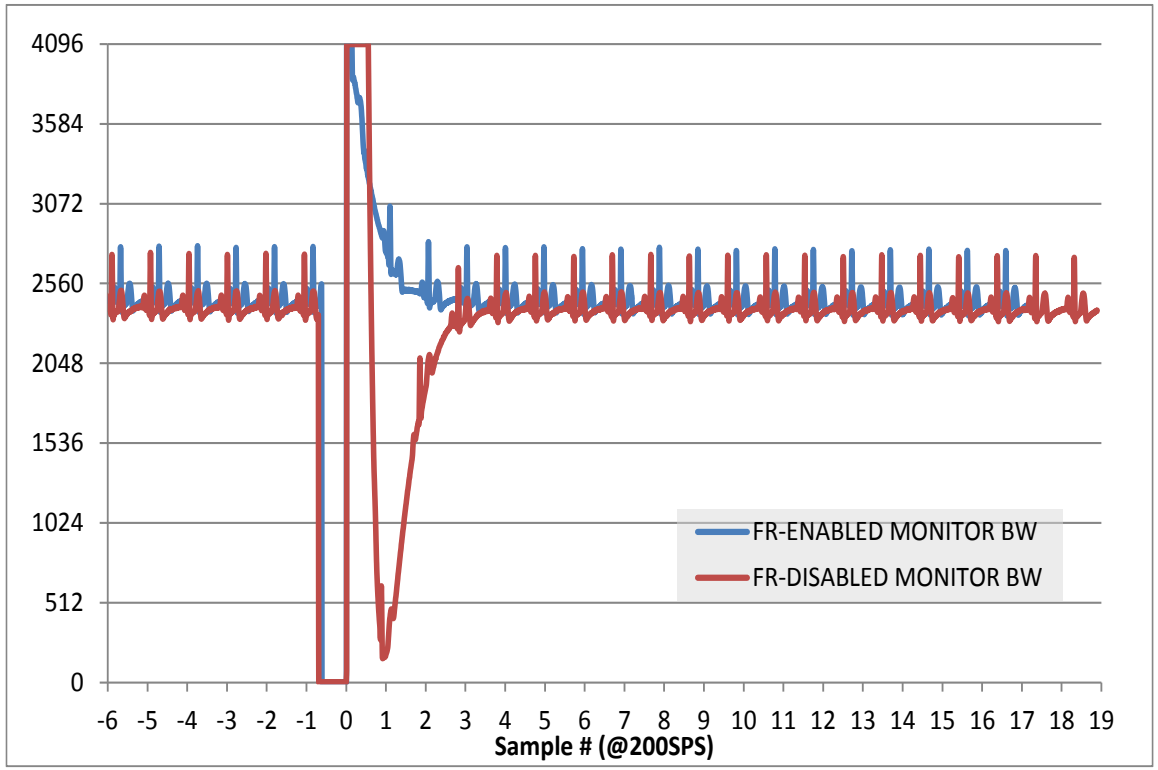
Fast Restore Feature





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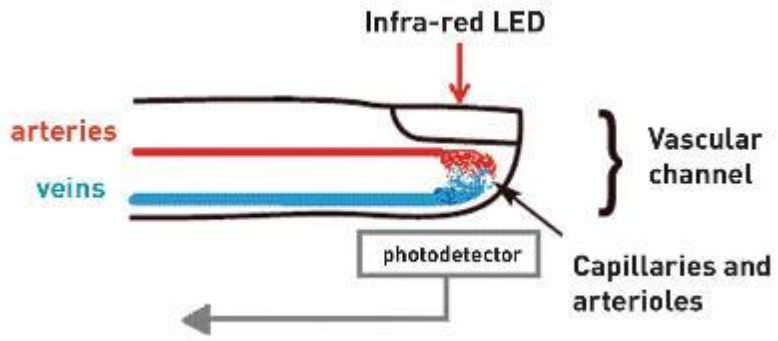
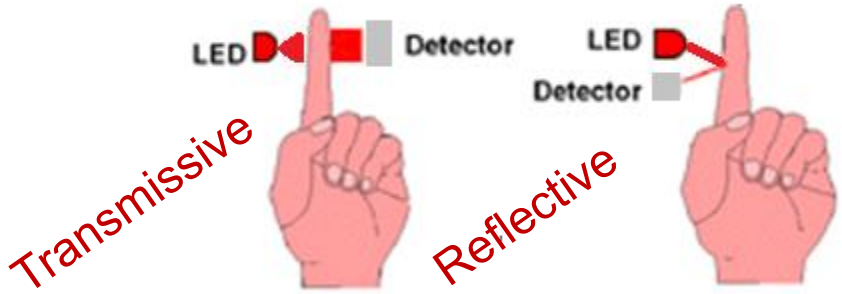
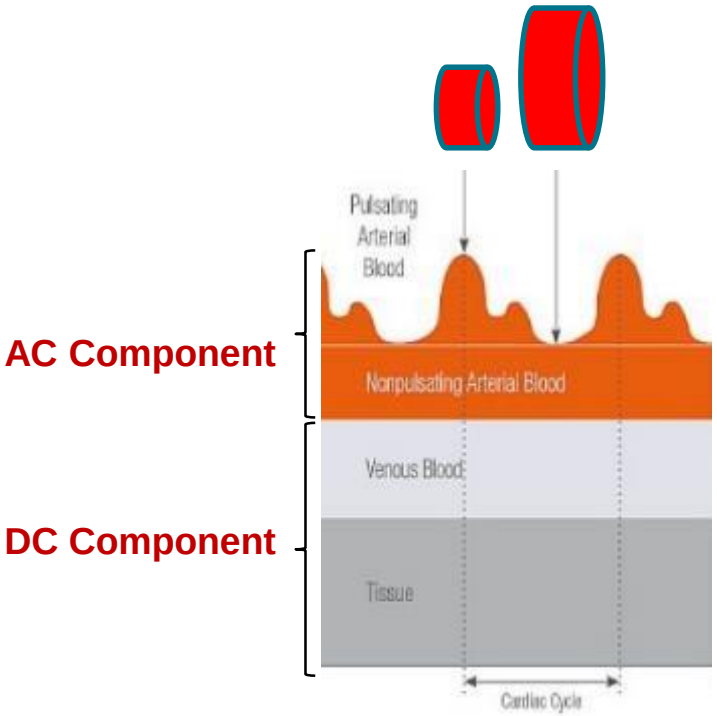
Optical Measurement

PPG Sensing Technology to Measure HRM and HRV

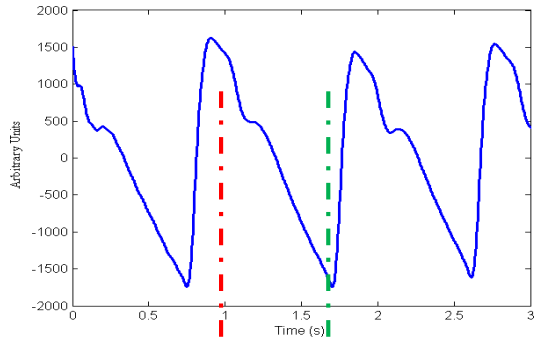
- **PPG: PhotoPlethysmoGraphy =** Method to monitor **pressure and volume** of a cardiovascular system
- **Transmissive:** Emitter and receiver are located at opposite faces of the sensed part. Light travels all along the flesh and is captured in the other face by the sensor.
- **Reflective:** Emitter and receiver are at the same face of the sensed part. Light penetrates the skin and a portion is reflected to the sensor.







Arterial diameter



Sensor PPG signal

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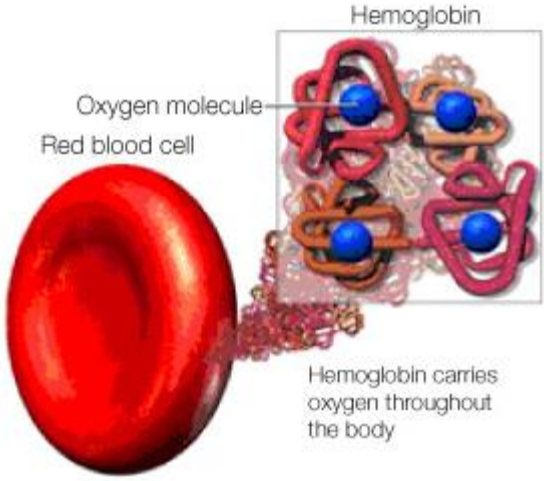
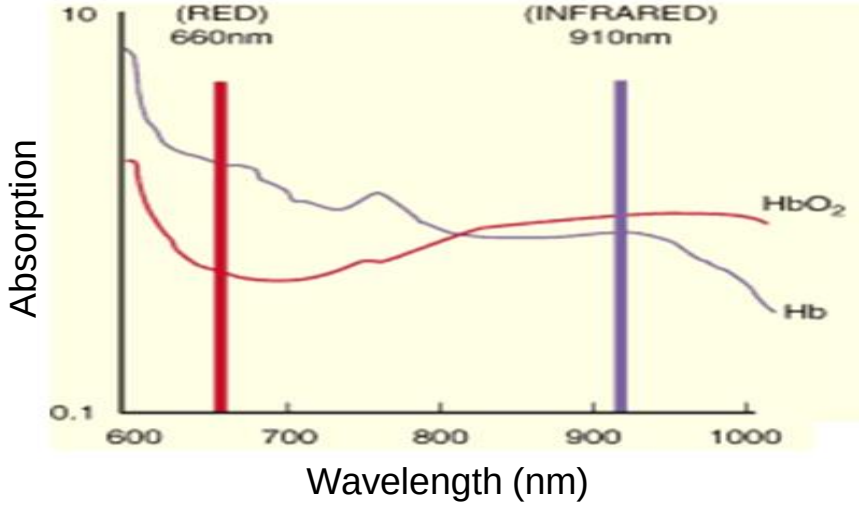
Using PPG for Measuring Oxygen Saturation (SPO2)





- SpO_2 is expressed as a ratio of Fully Saturated *Oxygenated Hemoglobin* (HbO_2) to *Total Hemoglobin (HbO_2 + Hb)* expressed in %
  - Typical reading is between 70% and 100%
- *SpO_2* goes up or down according to how well a person is breathing and how well the blood is being pushed around the body

Optical Receive Signal Chain and ADPDxxxx family

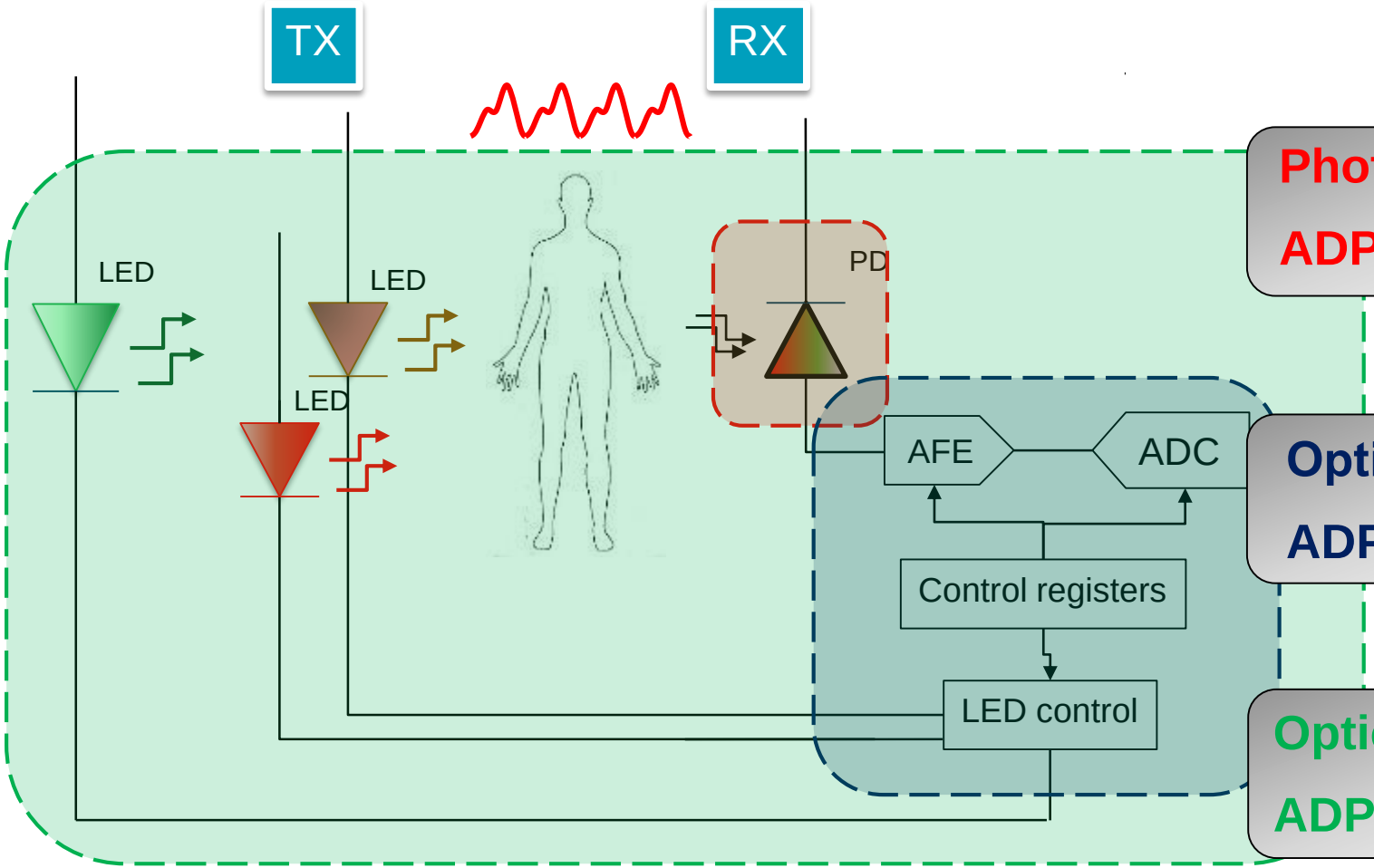
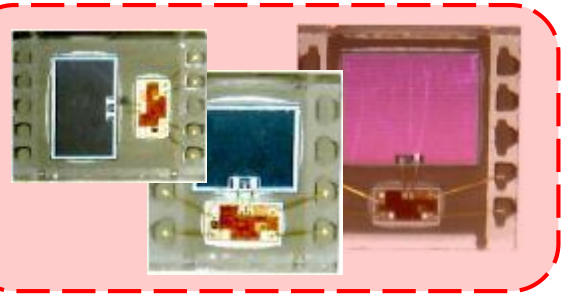


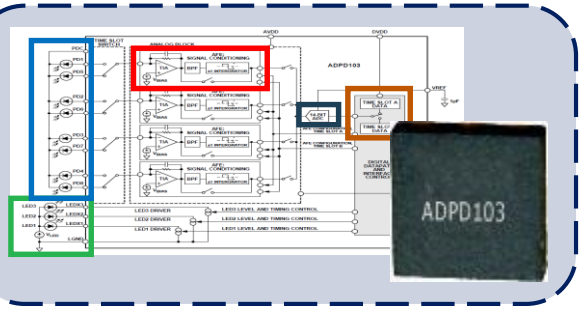
Photo Sensors

ADPD22xx



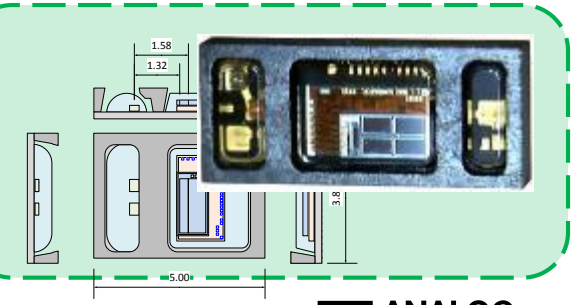
Optical AFE's

ADPD10x/108x



Optical Modules

ADPD14x/17x/18x



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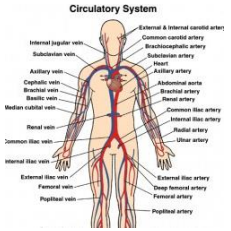
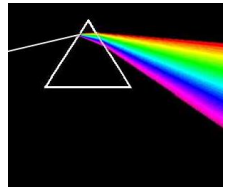
Challenges of Designing an Optical System

- Interference of Ambient Light
  - External Light sources are disturbing the receive signal
  - Cancel out by mechanical Design
  - Use smart Ambient light suppressing technologies
- The Artefacts of Motion
  - Integrate motion sensors for compensation (ADxL362)
  - Reduce motion artifacts by Mechanical design
- Physiology of the Human body
  - Body Location determines use case
  - Location and use-case define optical design
- Mechanical design and Optical Signal Path
  - Define optimal Photo Diode size & LED wavelengths
  - Optimum in PD / LED spacing
  - Coop with Optical Cross-Talk (ILP= Internal Light Pollution)





Optical Analog Front-Ends and Roadmap

ADPD105/106/107

- 4 Optical RX channels
- 3 LED Current sources up to 250mA
- Analog Ambient Light Rejection
- I2C and SPI Options
- EDA capability
- 2.7x improved SNR/Watt
- Improvements for longer battery life
- Enhanced triggering options

In Production

ADPD1080/ADPD1081

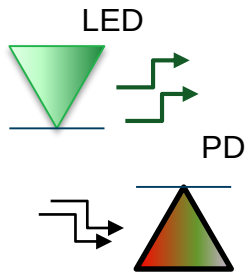
- Improved noise and power
- Improved PSRR
- Low voltage green LED operation capability
- Improved high sensitivity voltage measurement capability for ECG or other measurements
- Pin and register compatible with ADPD10X family of parts.

Just Released

Designing an Optical Signal Chain: Using Discretes or an Integrated Module?

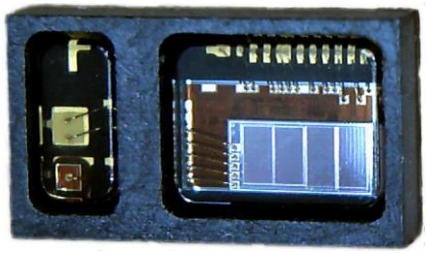
Discrete Solution

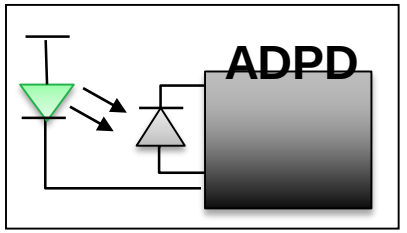
- Flexible in Photo Diode selection/size and LED-wavelength(s)
- Optimization possible for RX/TX sensor positioning
- Requires Optical / Mechanical & Electronic Design resources
- Optionally lenses and plastics needed
- Usually multiple design iterations required



Integrated Module

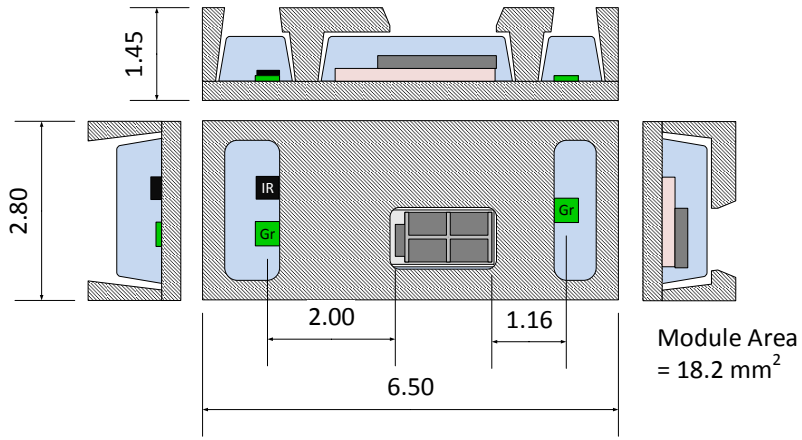
- Fixed sensor sizes
- Limitation on configuration options and positioning PD vs LEDs
- Fast design and shorter Time to market
- Less design knowledge required
- Superb solution behind glass window
- Small Form Factor



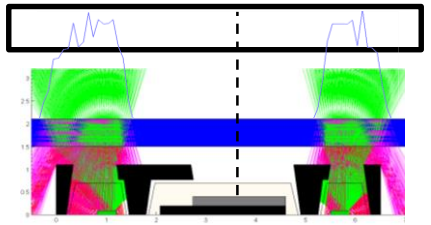


ADPD174GGI Optical Module and its Successor

ADPD174GGI: Released

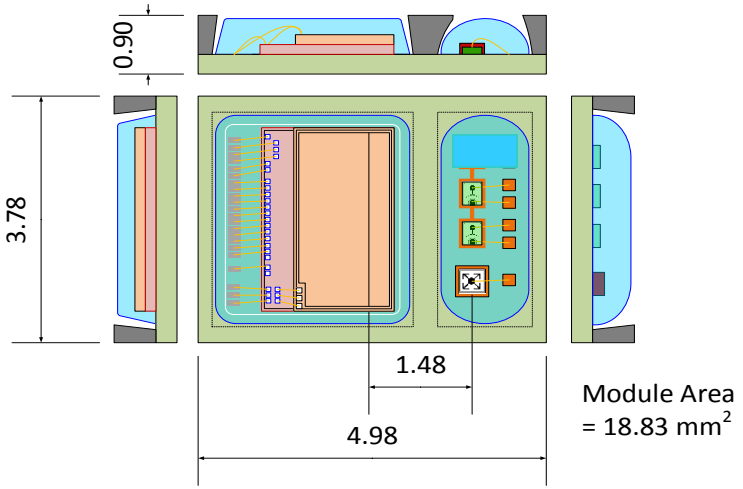


- Fully integrated module for Wrist PPG
- IR Led for proximity
- Low ILP (optical cross-talk) for good performance behind a transparent window



Best performing modules under glass window !!

ADPD188GG: Introduced Recently



- 3x to 6x better AC SNR for same Power (Dark Skin)
- Low profile design
- Enhanced “on-skin” detection.
- In-PD ambient rejection for ultra low noise
- Improved PSRR
- Separate ECG input with increased accuracy
- Low voltage green LED operation capable (remove boost conv.)

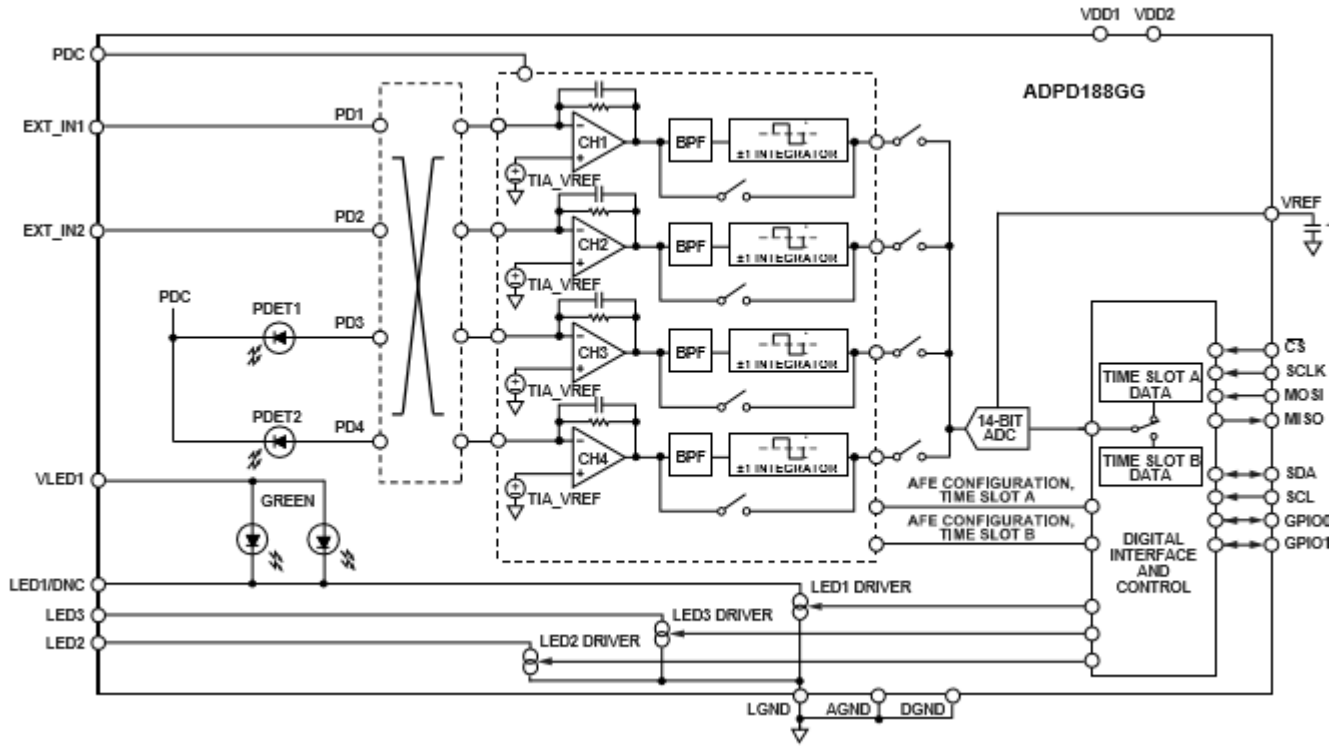
ADPD188GGZ: Optical Module designed for Optical HRM / HRV

Features

- Complete optical module, based on ADD108x + discrete optics
- Size Module 3.8mmxx 5.0mm x 0.9mm
- 2 Green LEDs, 2x PD + IR Cut Filter
- 2 Auxilary inputs
- Optimized SNR performance
- 3 LED Current Sources (370mA each)

Target Application

- Optical HRM / HRV
- Reflective SpO2 measurement
- Continuous Blood Pressure (CNiBP)



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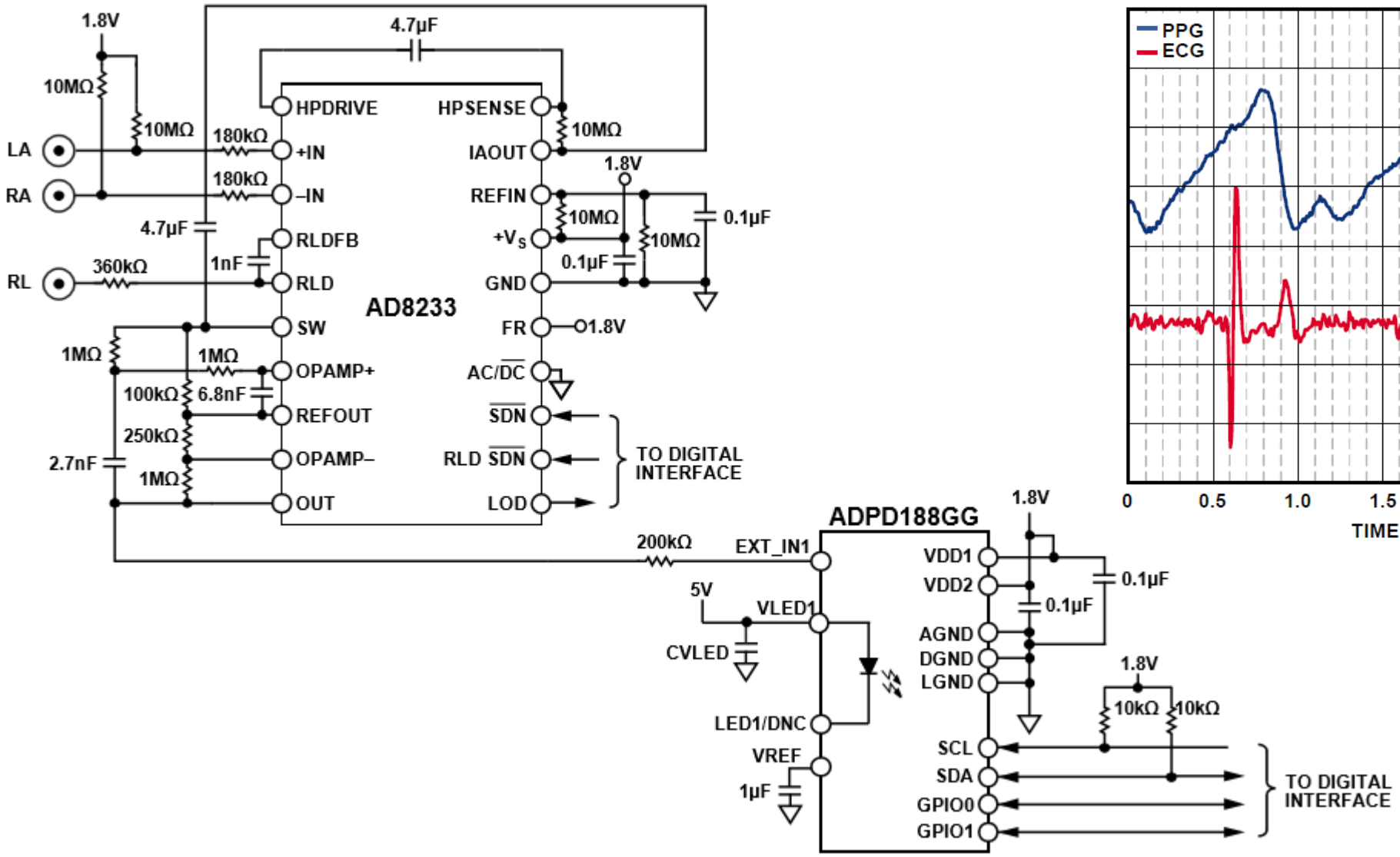
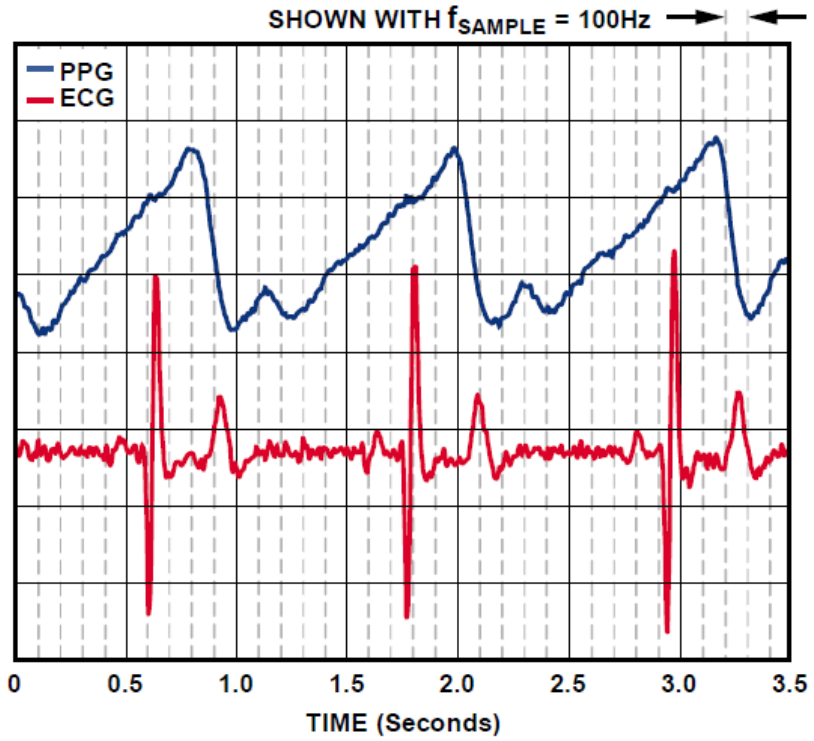
Overview ADPD Family Members

Part-Number	Target Application	Photo Diode Input(s)	Integrated Photo Diodes	LEDs / Channels	Comments
ADPD103BCPZ ADPD103BCBZ	Universal Optical AFE	4 (x2) Channels 1 (x2) Channels	No	3 Current Sources	4mmx4mm LFCSP 2.5x1.4mm WLCSP
ADPD105/6/7	2nd Gen Optical AFE	4 (x2) Channels 1 (x2) Channels	No	3 Current Sources	I2C / SPI Interface Improved SNR
ADPD1080/81	3rd Gen Optical AFE	4 (x2) Channels	No	3 Current Sources	Improved SNR-Power / Improved PSRR
ADPD142RG ADPD142RI	Heart Rate Mon. SPO2	4x 0.3mm2	Yes	1x Red, 1x Green 1x Red, 1x IR	
ADPD144RI	SPO2	4x 0.3mm2	Yes	1x Red, 1x IR	Improved ILP
ADPD153GGRIZ	Heart Rate Mon.	1x 0.9mm2 1x 0.3mm2	Yes	1x Red, 1x IR 2x Green	Split Window
ADPD173GGIZ	Heart Rate Mon.	1x 0.9mm2 1x 0.3mm2	Yes	1x IR / 2x Green	Improved ILP
ADPD174GGIZ	Heart Rate Mon.	1x 1.2mm2	Yes	1x IR / 2x Green	Improved ILP
ADPD18xGGIZ	Heart Rate Mon. / Proximity	1x 0.4mm2 1x 0.8mm2	Yes	1x IR / 2x Green	Improved Optical Performance / Aux Inputs

Synchronized ECG and PPG for None Invasive Blood Pressure Monitoring





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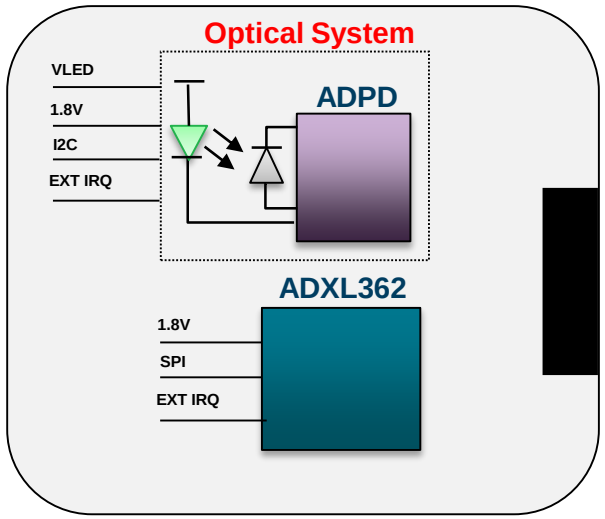
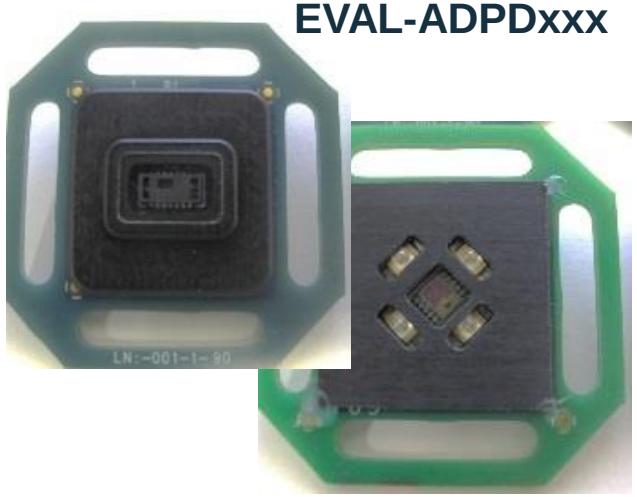
Optical Evaluation boards

Device Boards

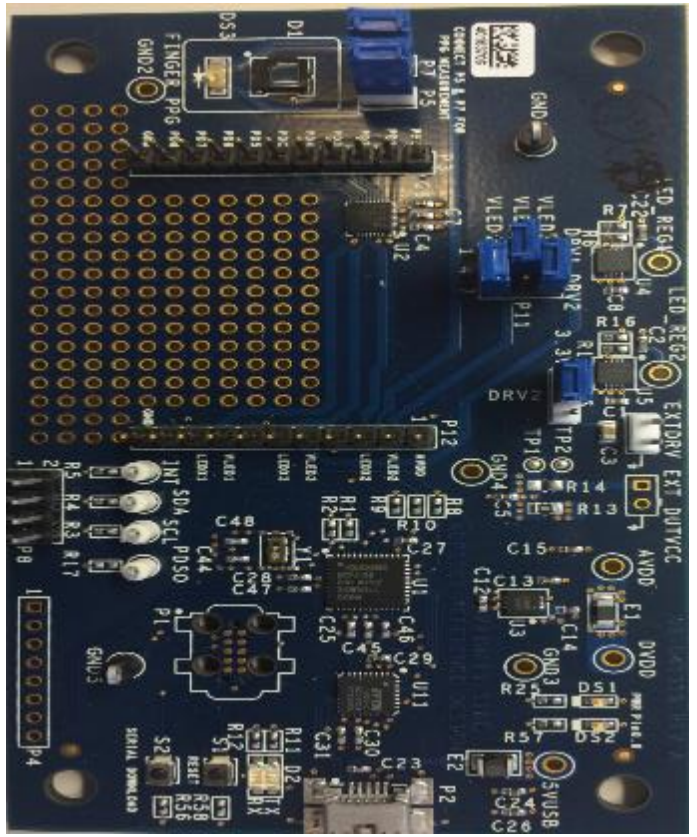


EVAL-ADPDxxx



Interface Board

EVAL-ADPDUCZ



EVAL-ADPD105Z-GEN

ANALOG DEVICES

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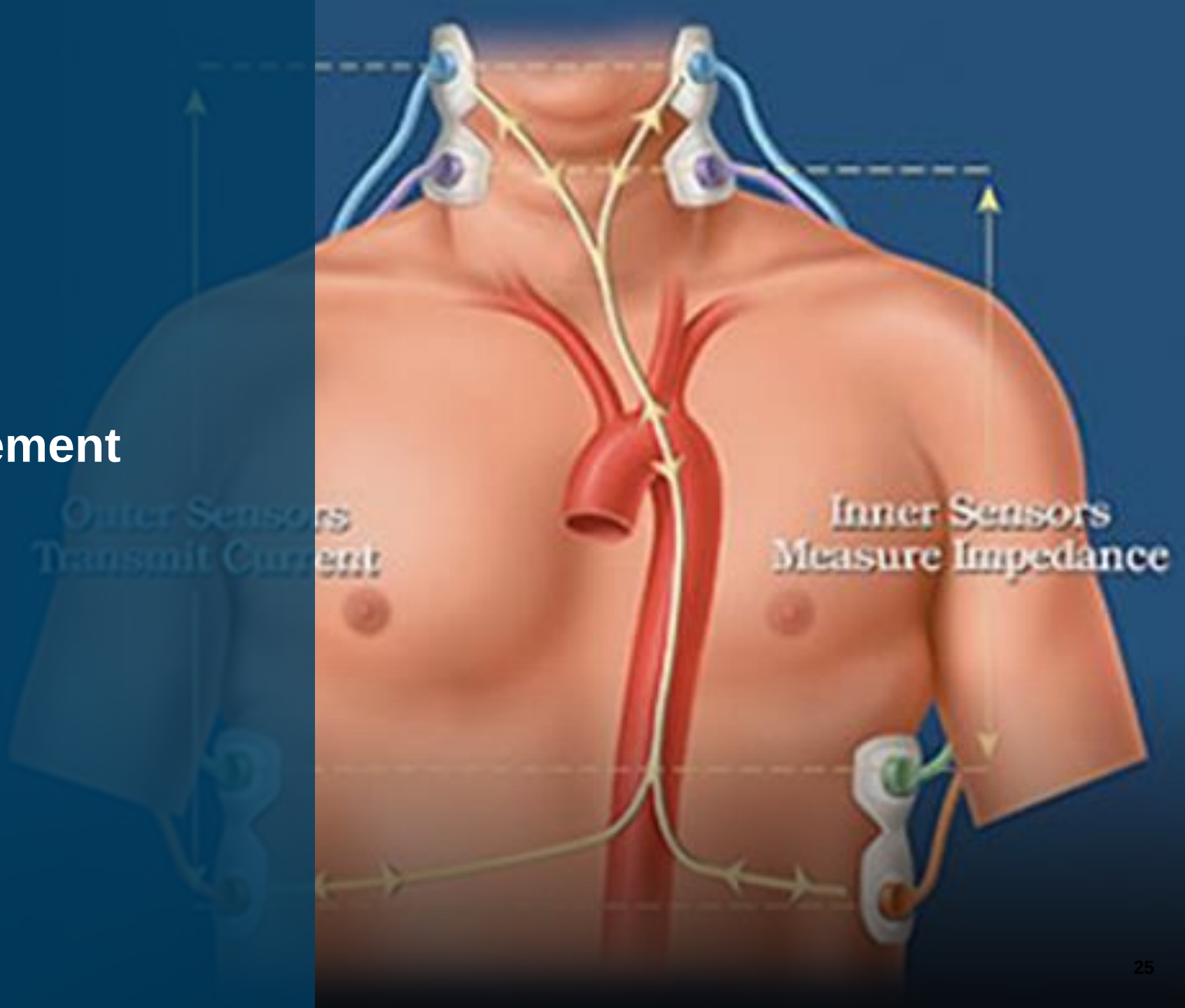
Bio-Impedance Measurement



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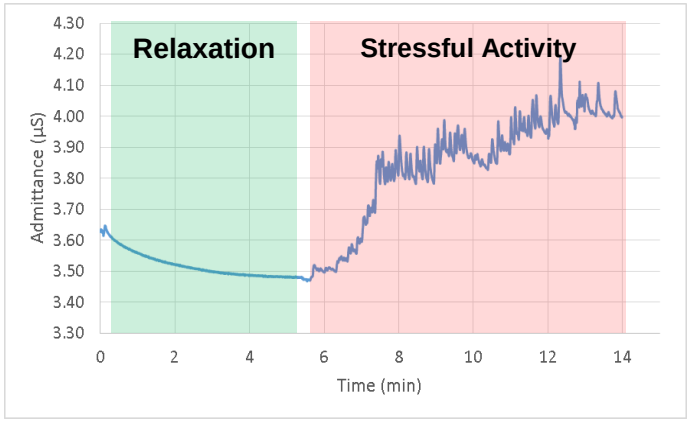
Various Bio-Impedance Measurement Use Cases

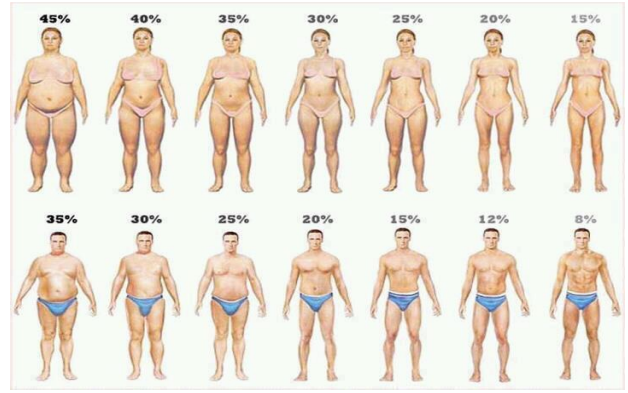
Applications and requirements

- **EDA/GSR (Electro Dermal Activity/Galvanic Skin Response)**
  - Skin (surface) Information
  - DC to 200Hz Excitation Signal
  - Always on Application - Continuous.
  - Stress and sleep monitoring



- **BCM/BIA (Body Composition Measurement / Bio Imp. Analyses)**
  - Cellular Application
  - Different tissue types: Fat, muscle, water, bone, etc.
  - 50kHz Excitation Signal
  - Twice a day - Non Continuous

- **Hydration**
  - Cellular Applications
  - Different body compartments: ICF, ECF, ISF, Plasma, etc..
  - Frequencies (50kHz, 100kHz, 150kHz, 200kHz)
  - Applications for both continuous and spot checks.



High Z ⟷ Low Z

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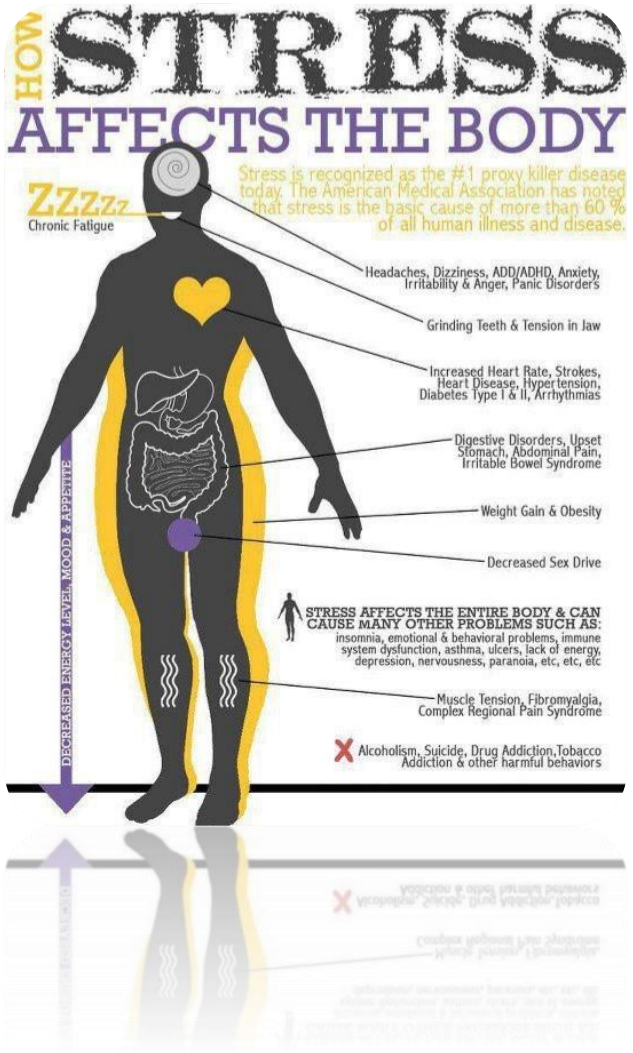
Electrodermal Activity to Measure Stress Level

Why is Stress Important?

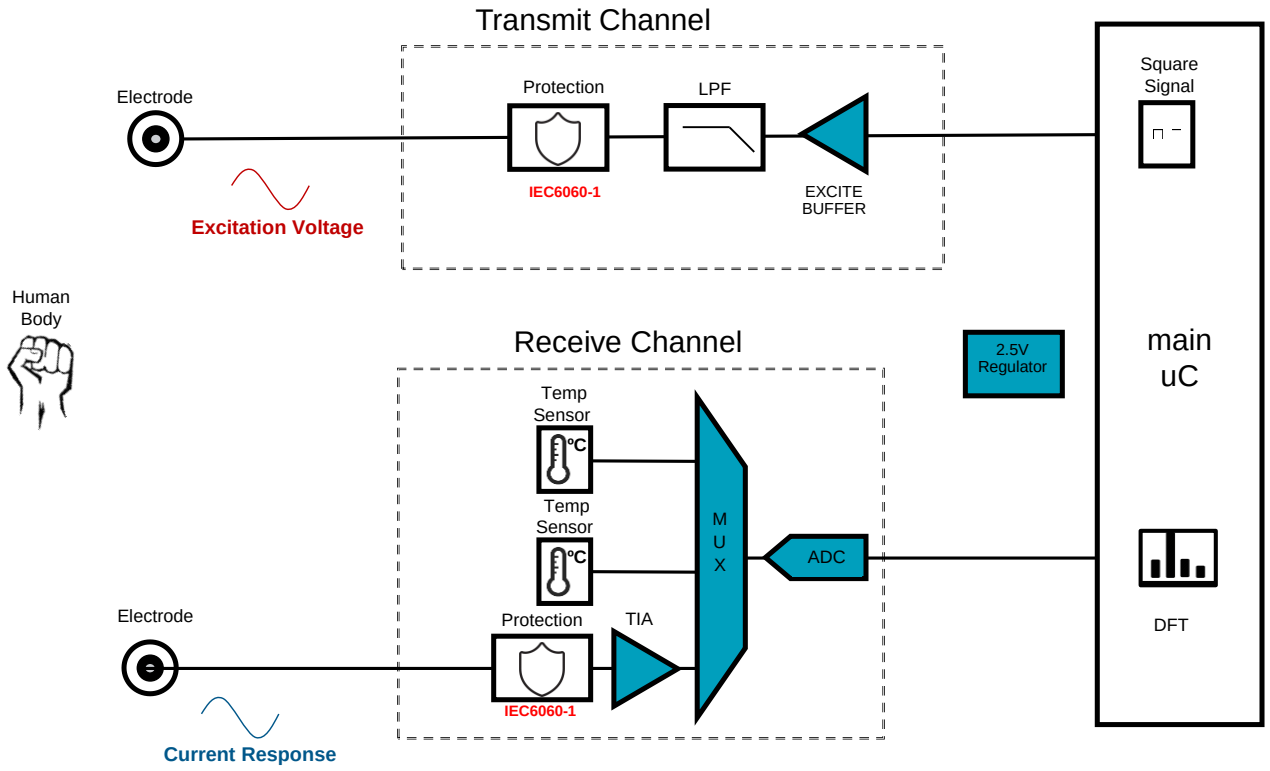
- Insomnia
- Eating disorders
- Depression
- Anxiety and panic attacks
- Colds and viruses
- Circulatory problems
- Systemic or local infections
- Diabetes
- Heart problems
- Cancer

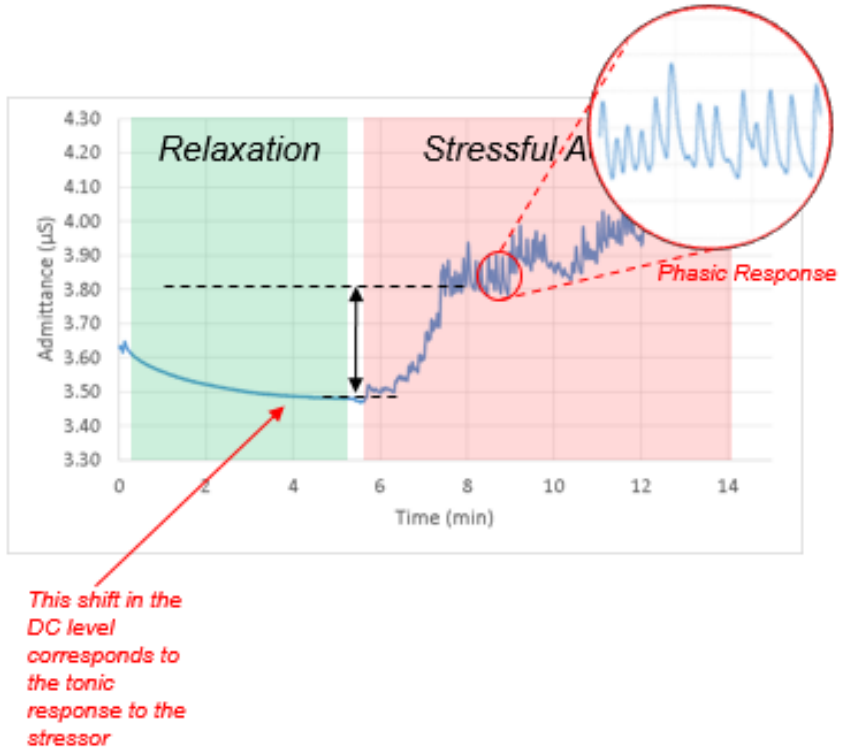
http://www.lifescript.com/well-being/articles/i/illnesses_caused_by_stress.aspx



Electrodermal Activity

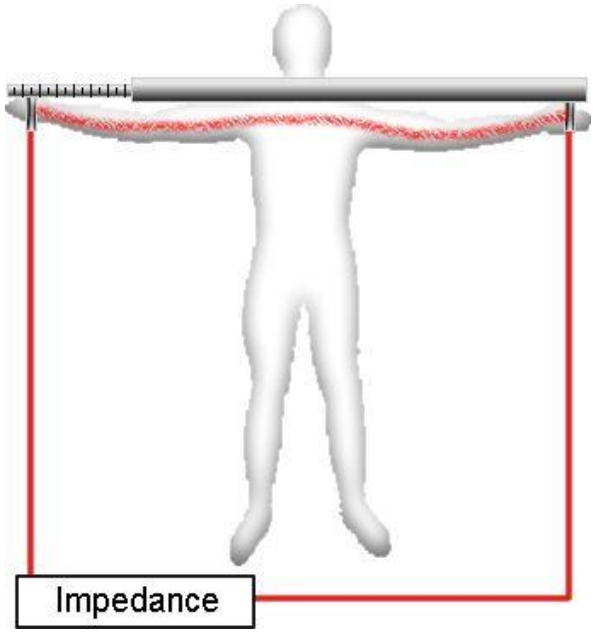
Discrete Solution To Measure EDA

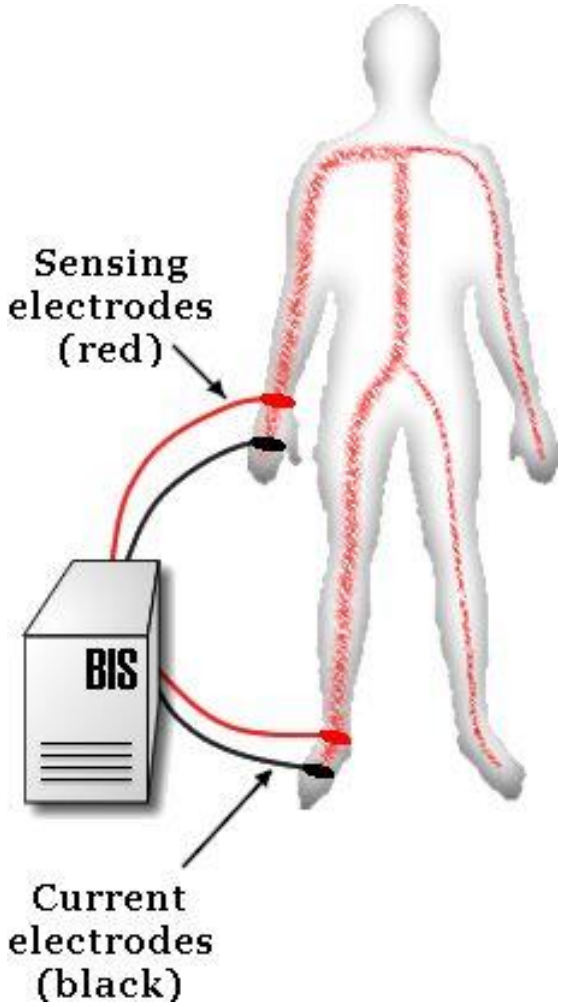


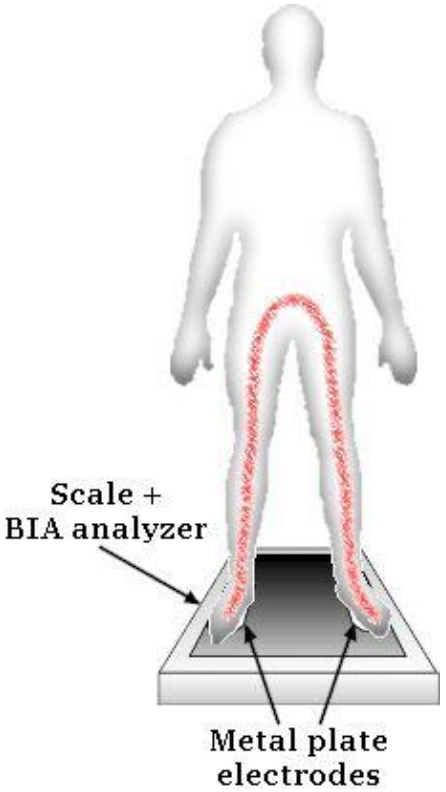


Body Impedance

Bioelectrical Impedance Analysis (BIA)





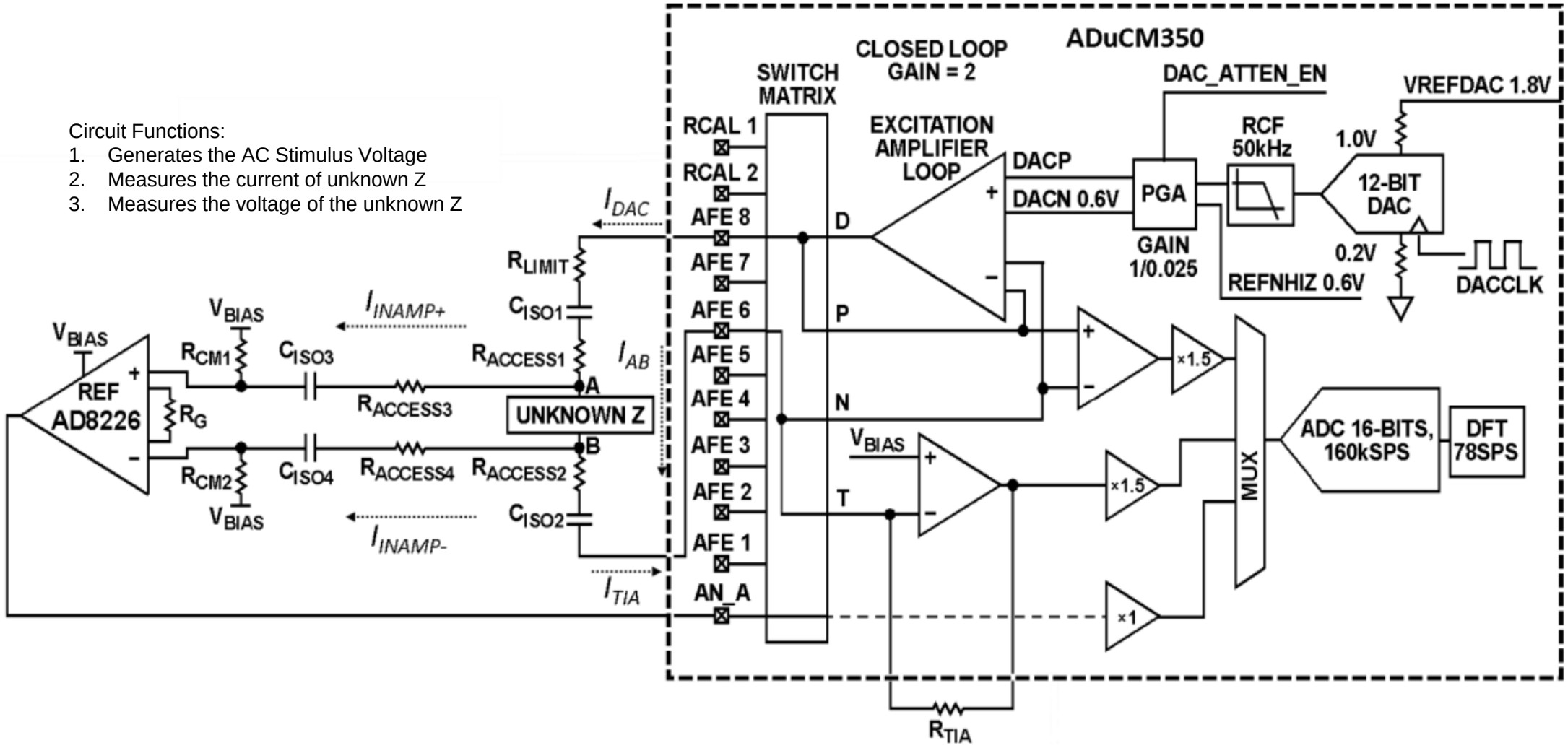


Body Impedance

4-Wires ADuCM350 circuit – IEC60601

Circuit Functions:

1. Generates the AC Stimulus Voltage
2. Measures the current of unknown Z
3. Measures the voltage of the unknown Z



ANALOG DEVICES

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Motion Sensing

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Motion Sensing with MEMS Ultra Low Power Components

Pivot to Higher Value Healthcare

Classical HCR use-cases

AED Support

Prosthesis Control

Blood-pressure Monitors

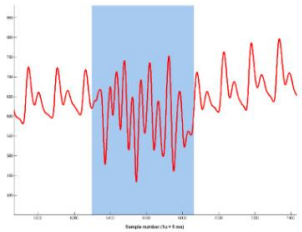
(Level Control)

MEMs in Wearables

(24/7)

- Motion Tracking/Profiling

- Motion Artifact Rejection



- Step Counting

- Calorie Burn

- Fall Detection

ANALOG DEVICES
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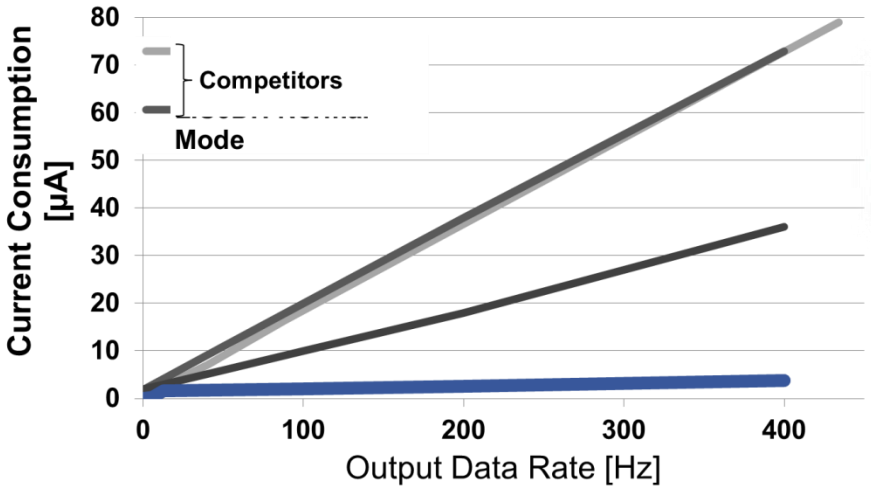
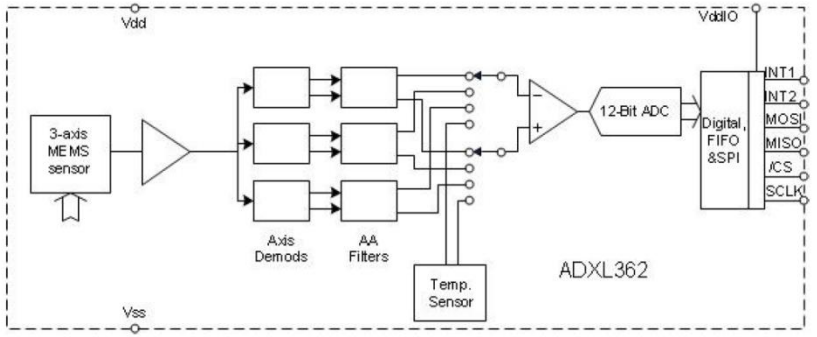
ADXL362 Micropower Three-Axis, ±2*g*/4*g*/8*g* Digital XL

Industry's Lowest Power MEMS Accelerometer

- **Ultra-low power**
  - **300 nA motion-activated Wake-up Mode**
  - **3.0 µA across full ODR up to 400Hz @ 12-bit resolution**
  - **10nA Standby current**
- **Many built-in features for system-level power savings, including:**
  - **Adjustable-threshold sleep/wake modes for motion activation**
  - **Multiple sample activity detection to eliminate "false positive" motion**
  - **Deep embedded FIFO minimizes host processor load**
- **Continuous sampling up to 400Hz ODR → no undersampling or aliasing!**
- **12-bit resolution: 1 m*g*/LSB @ ±2*g* range**
- **Low noise down to 175 µ*g*/√*Hz***
- **Wide supply and I/O voltage ranges: 1.6 V to 3.6 V**
- **Acceleration sample synchronization via external trigger**
- **Small and thin 3 mm × 3.25 mm × 1.06 mm package**





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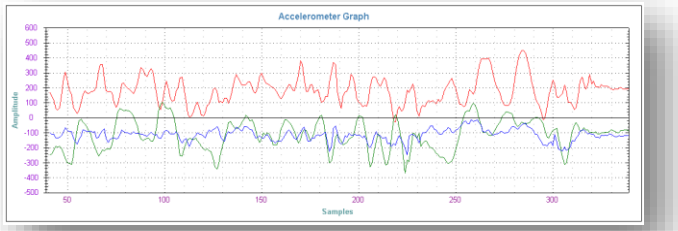
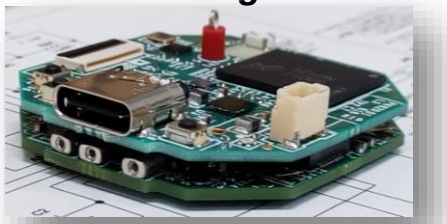
One Stop Shop for Wearable VSM

Motion: ADxL36x Family

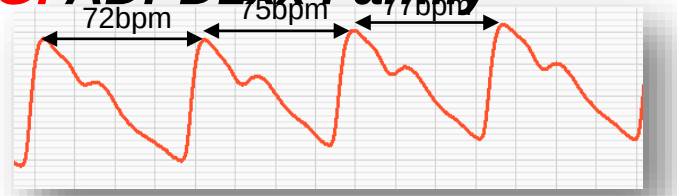


Modular Design



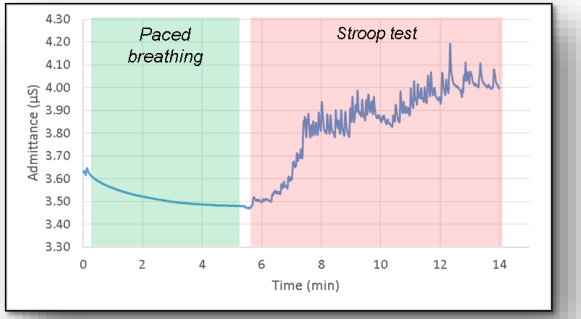
ADI Health Platform

PPG: ADPD1xx Family

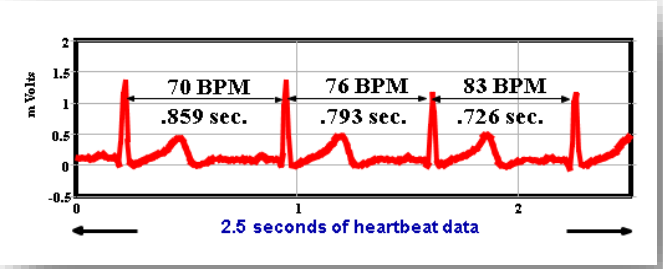


SKIN TEMP: ADT7xxx

EDA/GSR: AD59xx / M350



ECG: AD823x / ADAS1k



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