A Precision Low-Level DAS/ECG Cardiotachometer Demo Board

Created by Dr. John Brown

Prepared by Thomas Kuehl & Laura Groskie

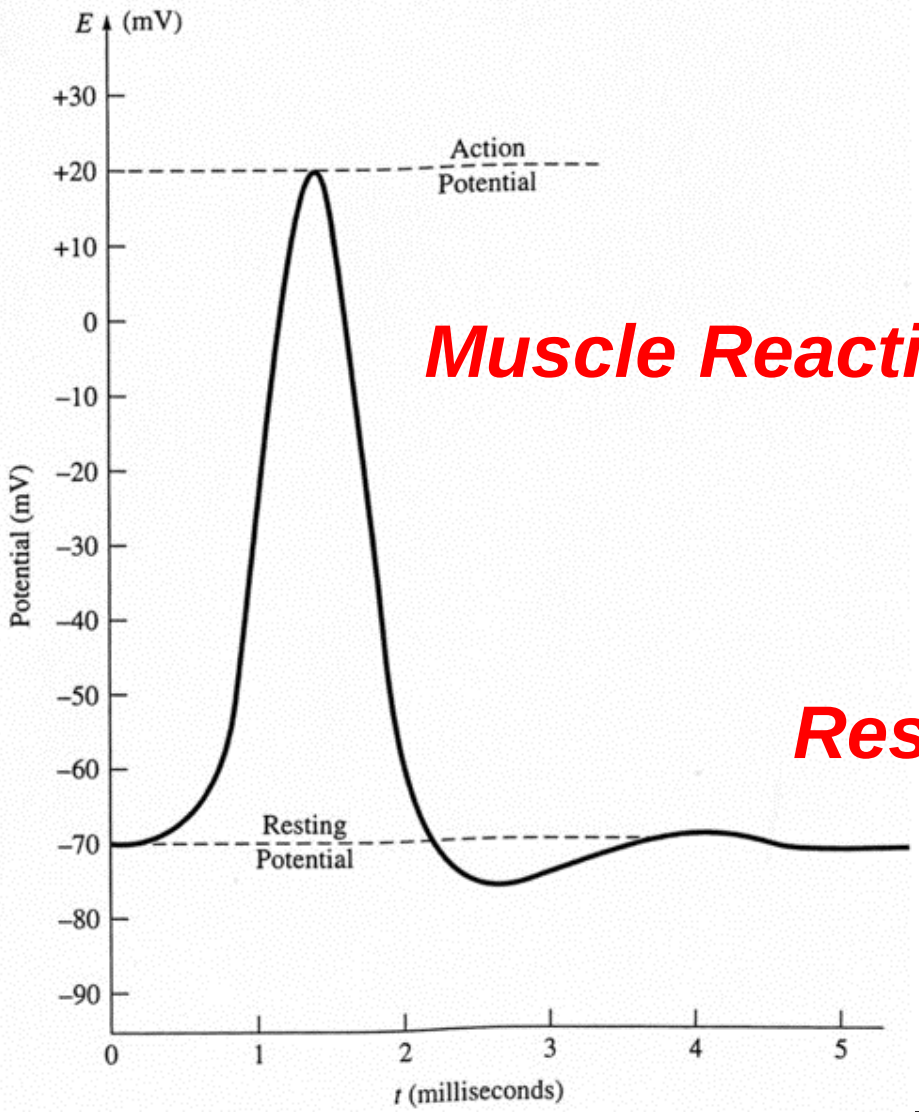
Texas Instruments – Tucson, AZ

A Precision Low-Level DAS/ECG Cardiotachometer Demo Board

Presentation Outline

- Biopotentials
- Electrocardiogram, ECG
- ECG characteristics
- ECG electrodes and connections
- The DAS/ECG board electrical functions and capabilities
- AC and DC applications for the DAS/ECG board

Biopotentials – Muscle Cell



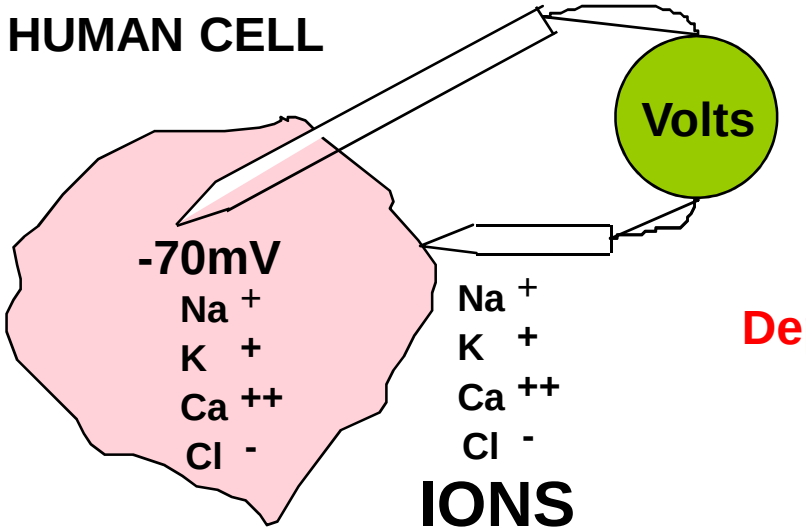
Muscle Reaction

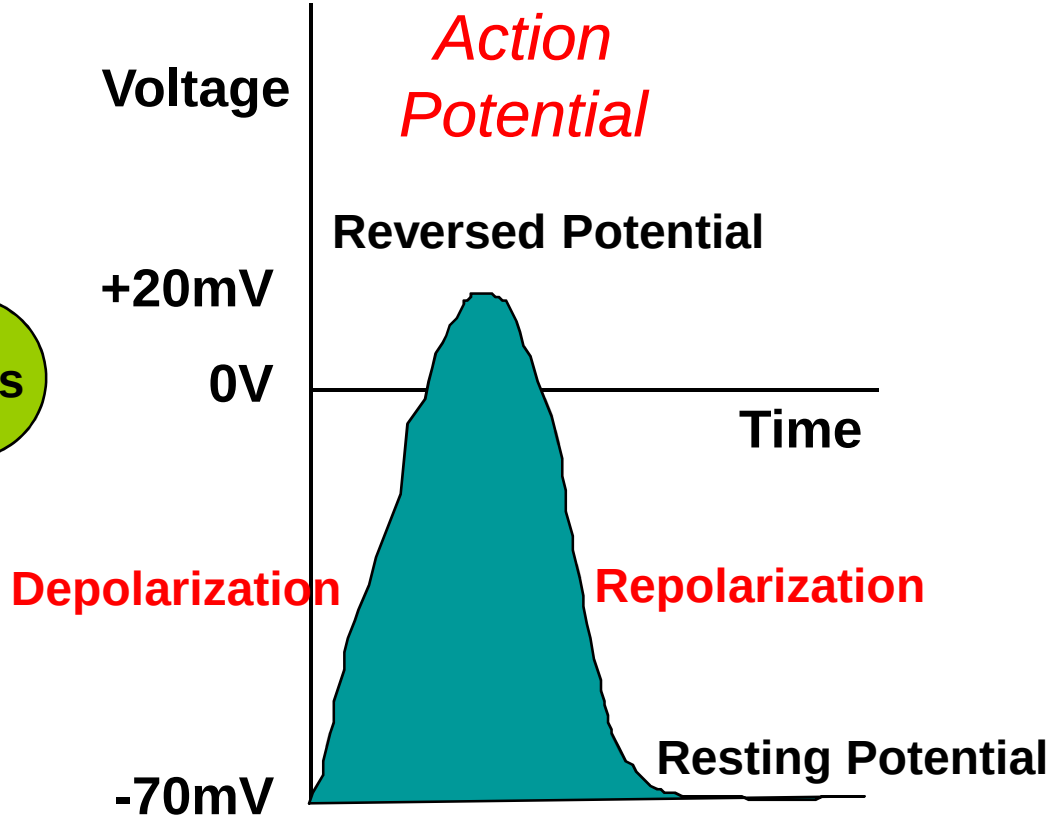
Resting State

Biopotentials from Cells

Electrical Signals From the Body

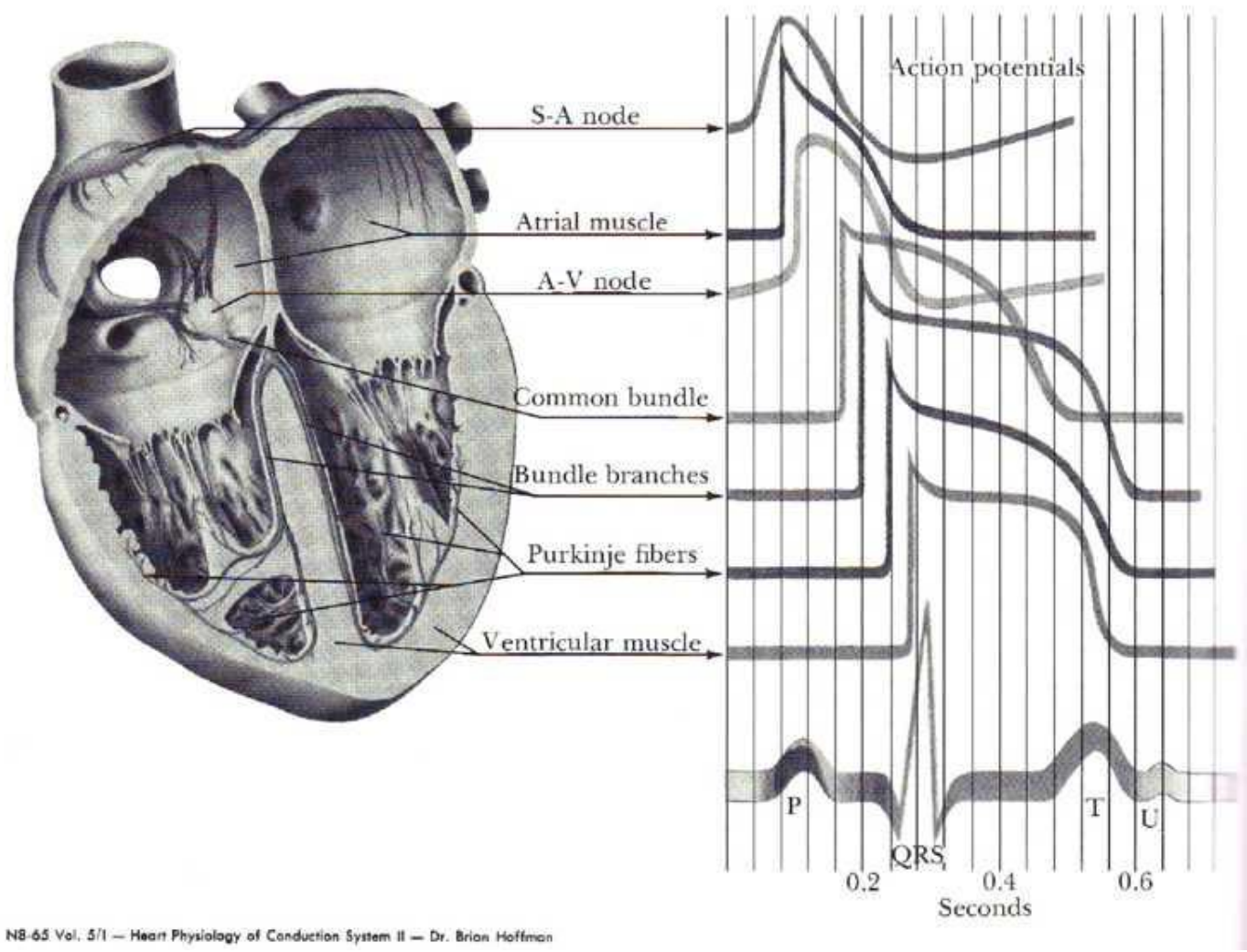
EVERY CELL IS LIKE A LITTLE BATTERY





Biopotentials from Cells

Electrical Signals From the Heart

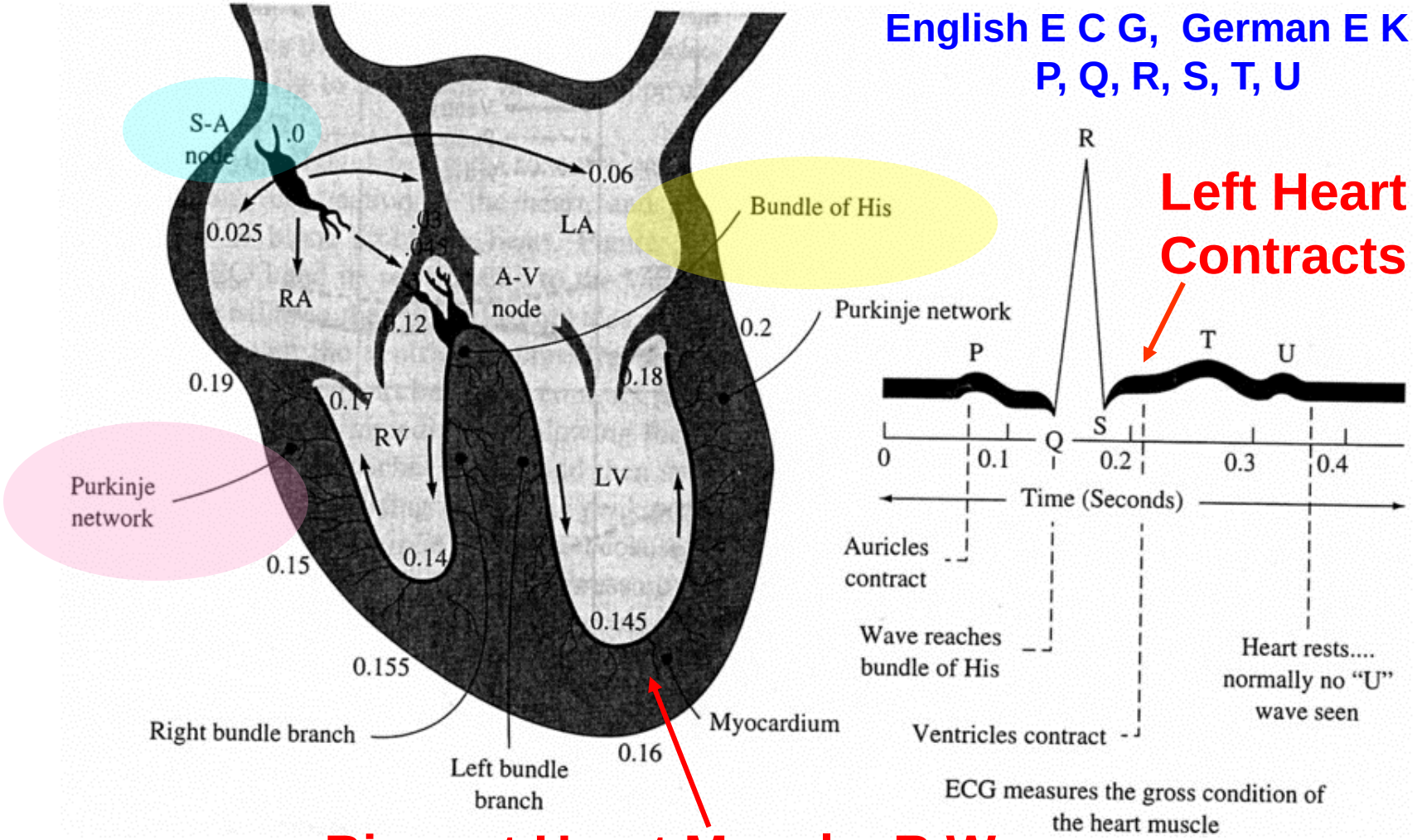


NB-65 Vol. 5/1 — Heart Physiology of Conduction System II — Dr. Brian Hoffman

Cardiac Conduction System of the Heart

ECG Waveforms

English E C G, German E K G
P, Q, R, S, T, U

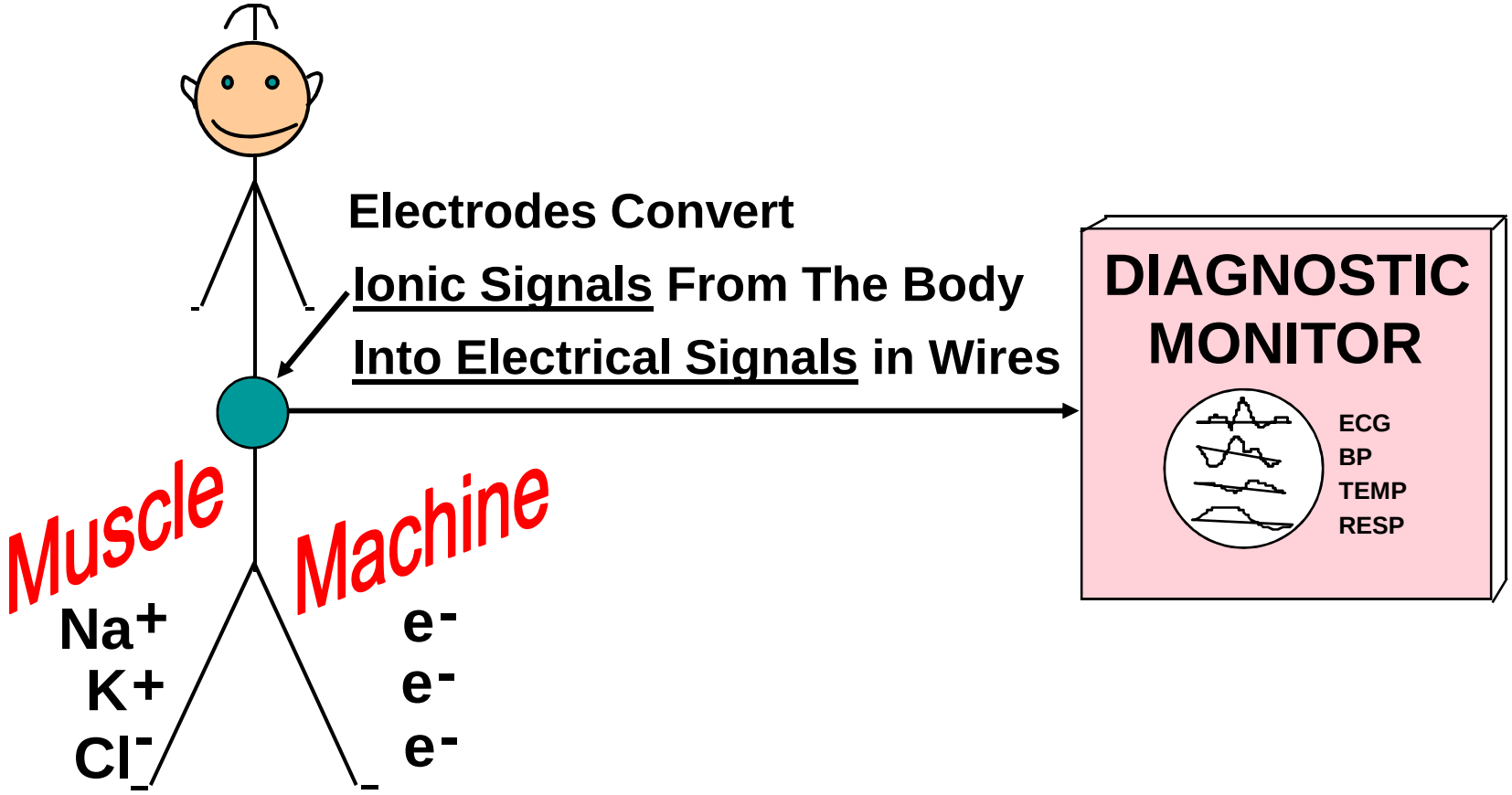


Left Heart Contracts

Biggest Heart Muscle, R Wave

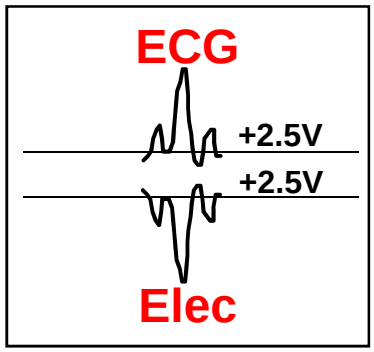
Biopotentials from Cells - Electrodes

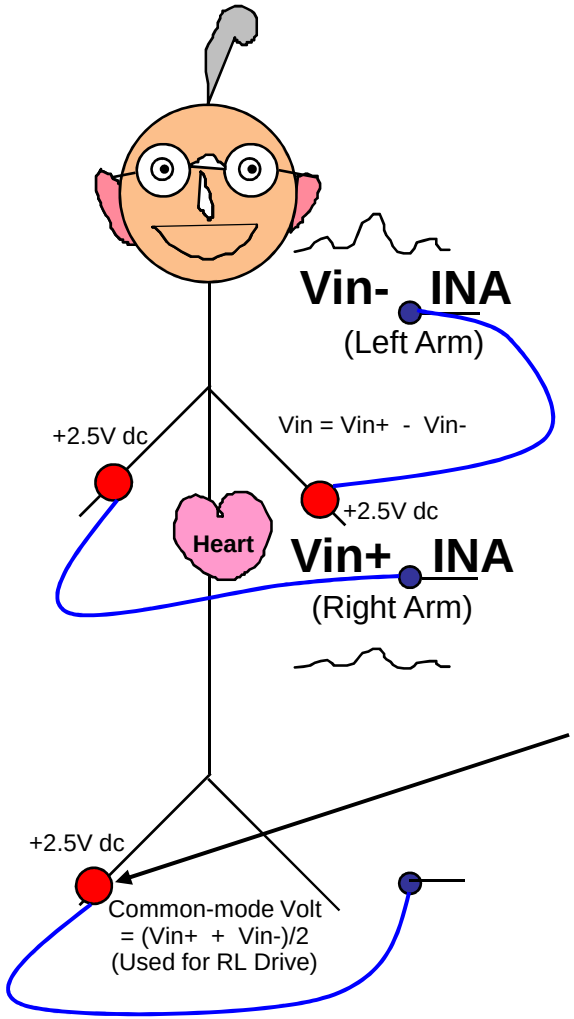
IONS to ELECTRONS CONVERTER



Basic ECG electrode connections

ECG is Measure of Heart as a Ionic or Electrical Generator





Electrocardiogram Records Electrical Changes From Beating Heart

Electrodes Transduce Ions Into Electrons

ECG Einthoven Triangle, 1907

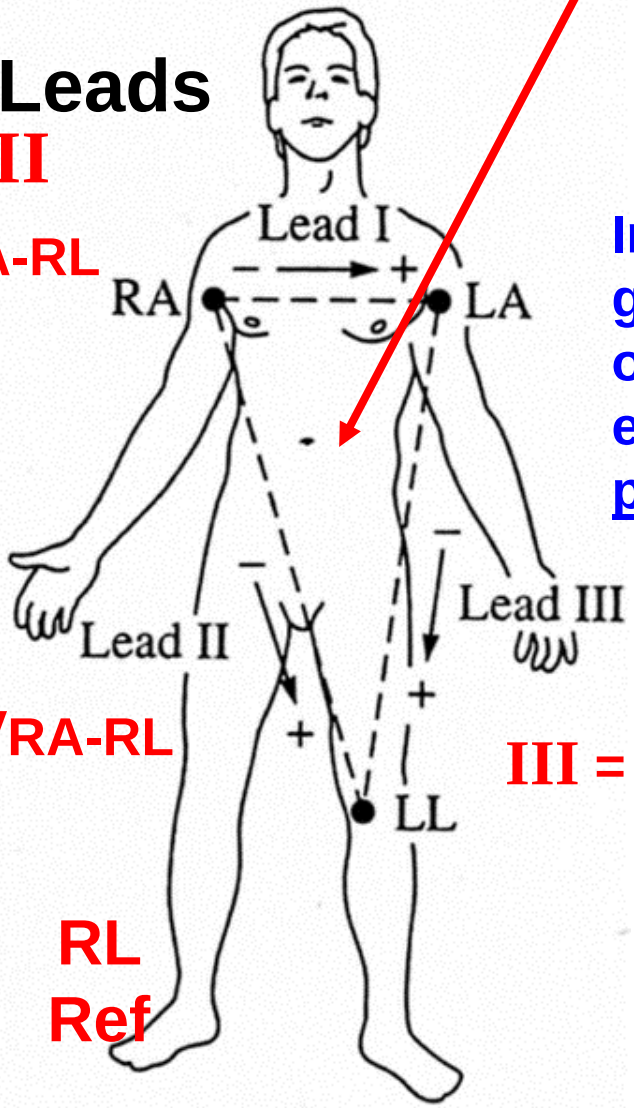
3 Derived Leads
I, II, III

I = $V_{LA-RL} - V_{RA-RL}$

II = $V_{LL-RL} - V_{RA-RL}$

III = $V_{LL-RL} - V_{LA-RL}$

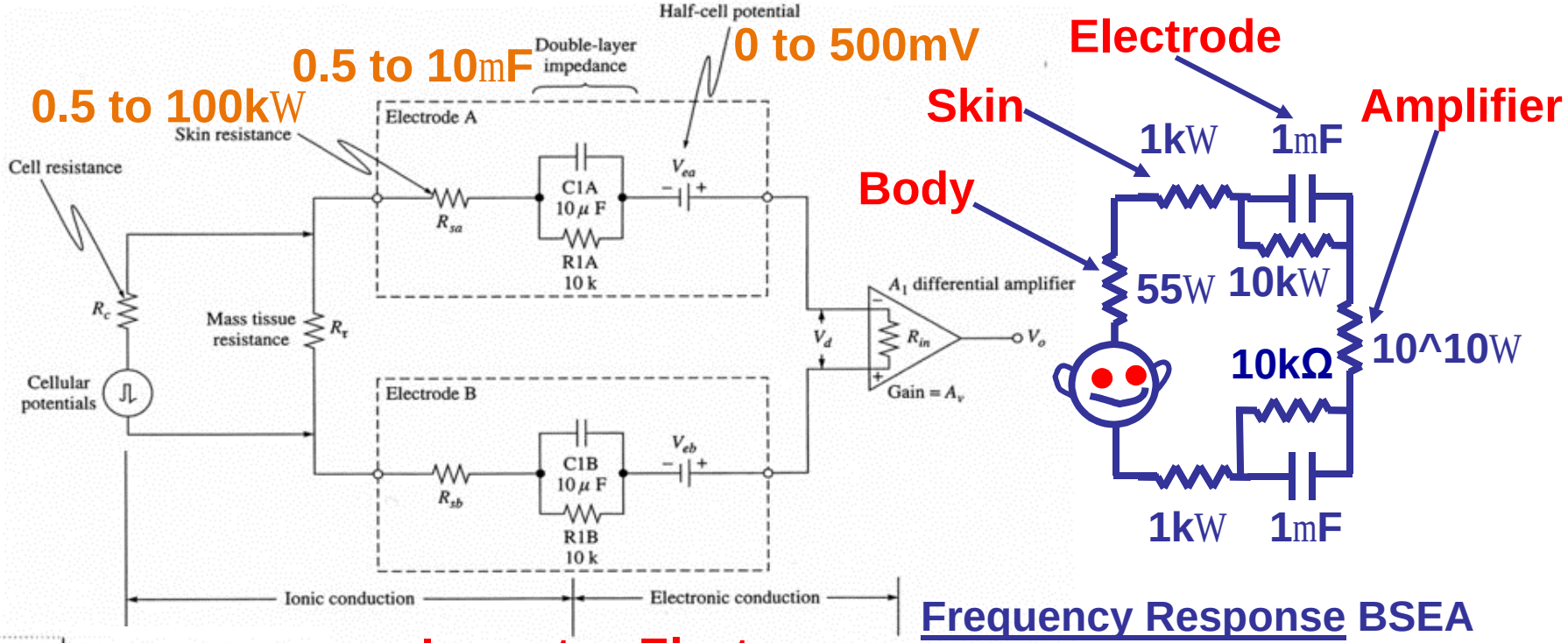
3 Body Electrodes

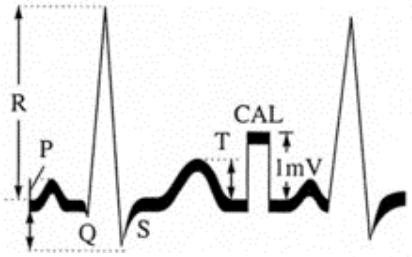


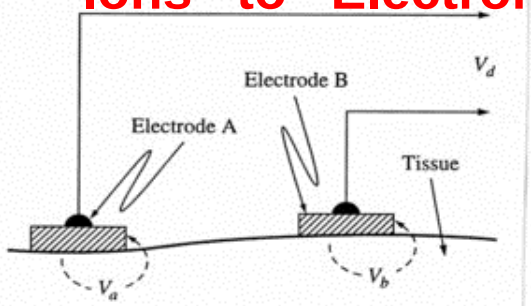
Einthoven's Law

In electrocardiogram at any given instant the potential of any wave in Lead 2 is equal to the sum of the potentials in Lead I and III.

ECG Electrode – Electrical Model







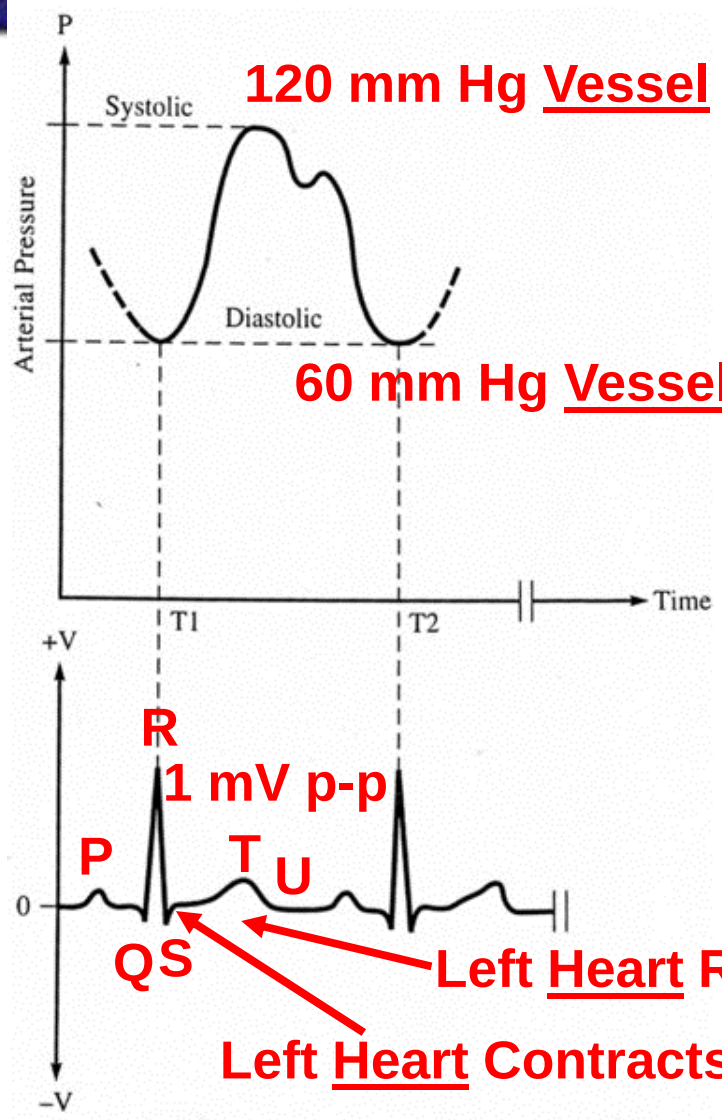
Frequency Response BSEA

Fo = 1 / 2 π RC

Fo = 0.159 / (1kW) (1mF)

= 159Hz

ECG and Blood Pressure Waves



120 mm Hg Vessel Maximum Pressure Head

Pressure signal has slower rise

30Hz BW, 25 harmonics

60 mm Hg Vessel Relaxation

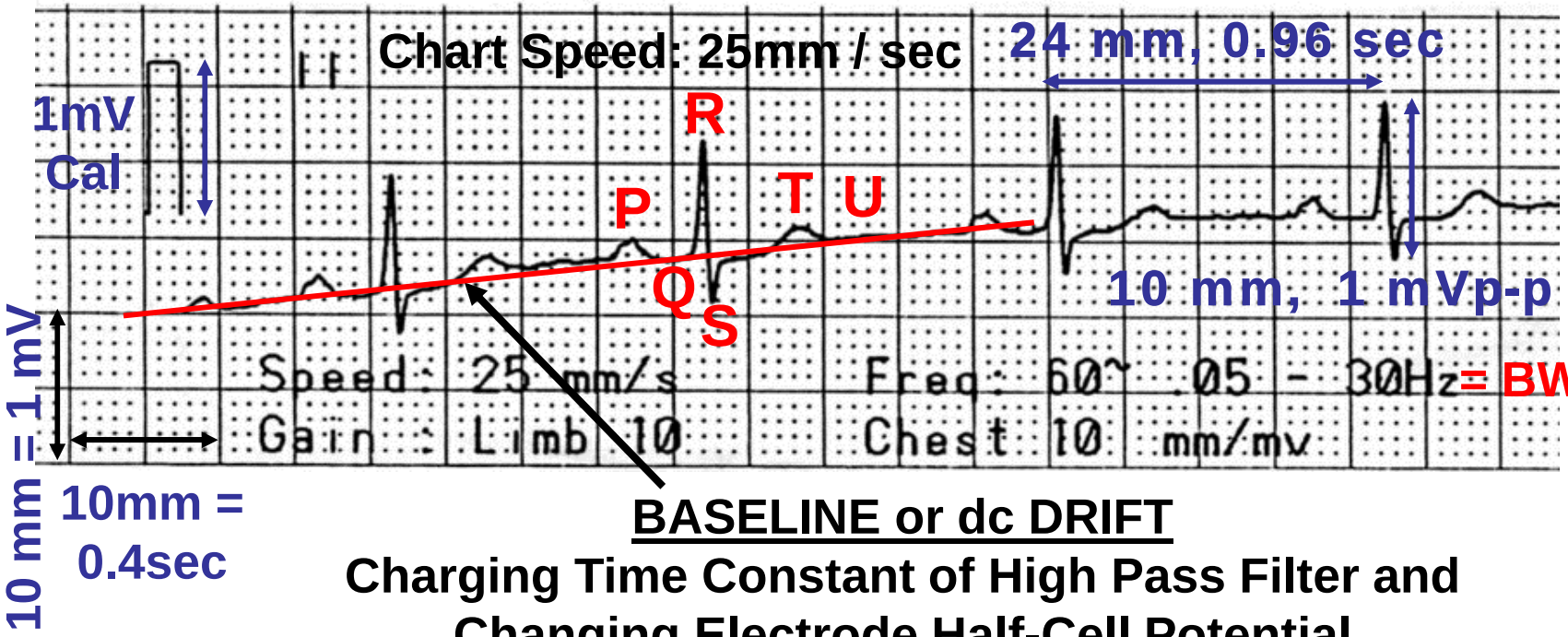
ECG signal has faster rise

100Hz BW, 70 harmonics

Left Heart Relaxes

Left Heart Contracts

Actual ECG - Normal



BASELINE or dc DRIFT

Charging Time Constant of High Pass Filter and Changing Electrode Half-Cell Potential

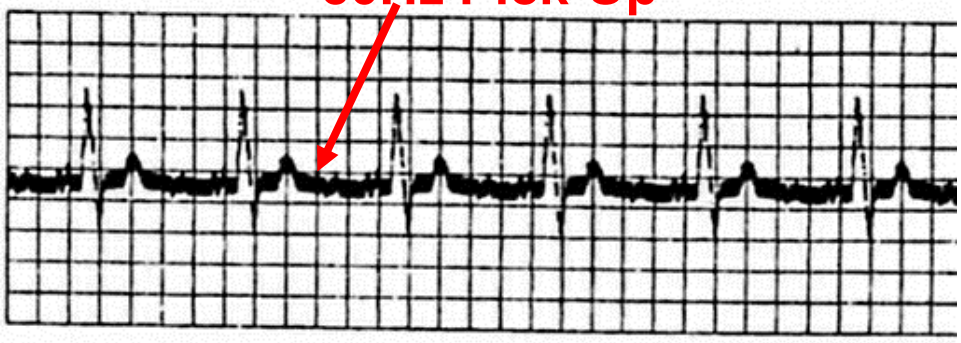
24 mm x 1 sec / 25mm = 0.96 sec / beat => 1 / 0.96 sec = 1.04 bps

62 bpm

at rest

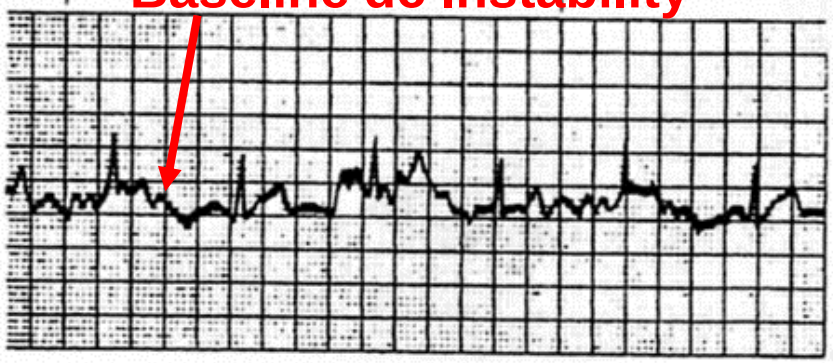
ECG Irregular Tracings Due to Artifacts

60Hz Pick-Up



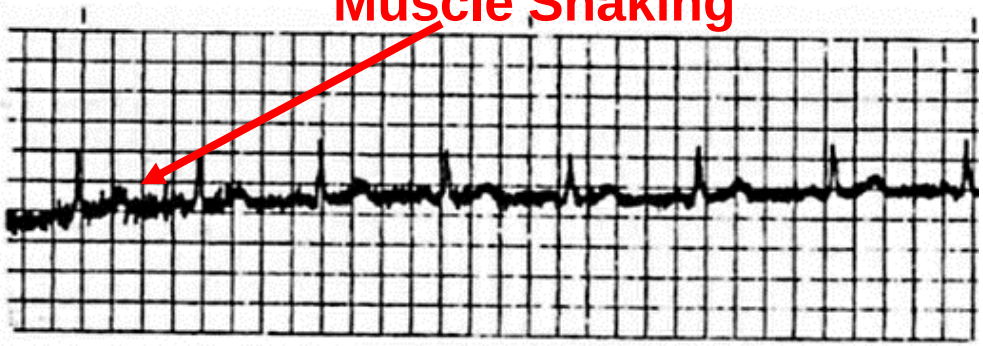
ALTERNATING CURRENT (AC) INTERFERENCE

Baseline dc Instability



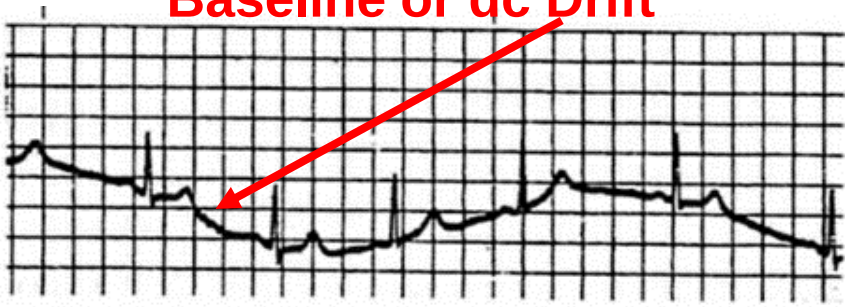
IRREGULAR BASELINE

Muscle Shaking



SOMATIC TREMOR

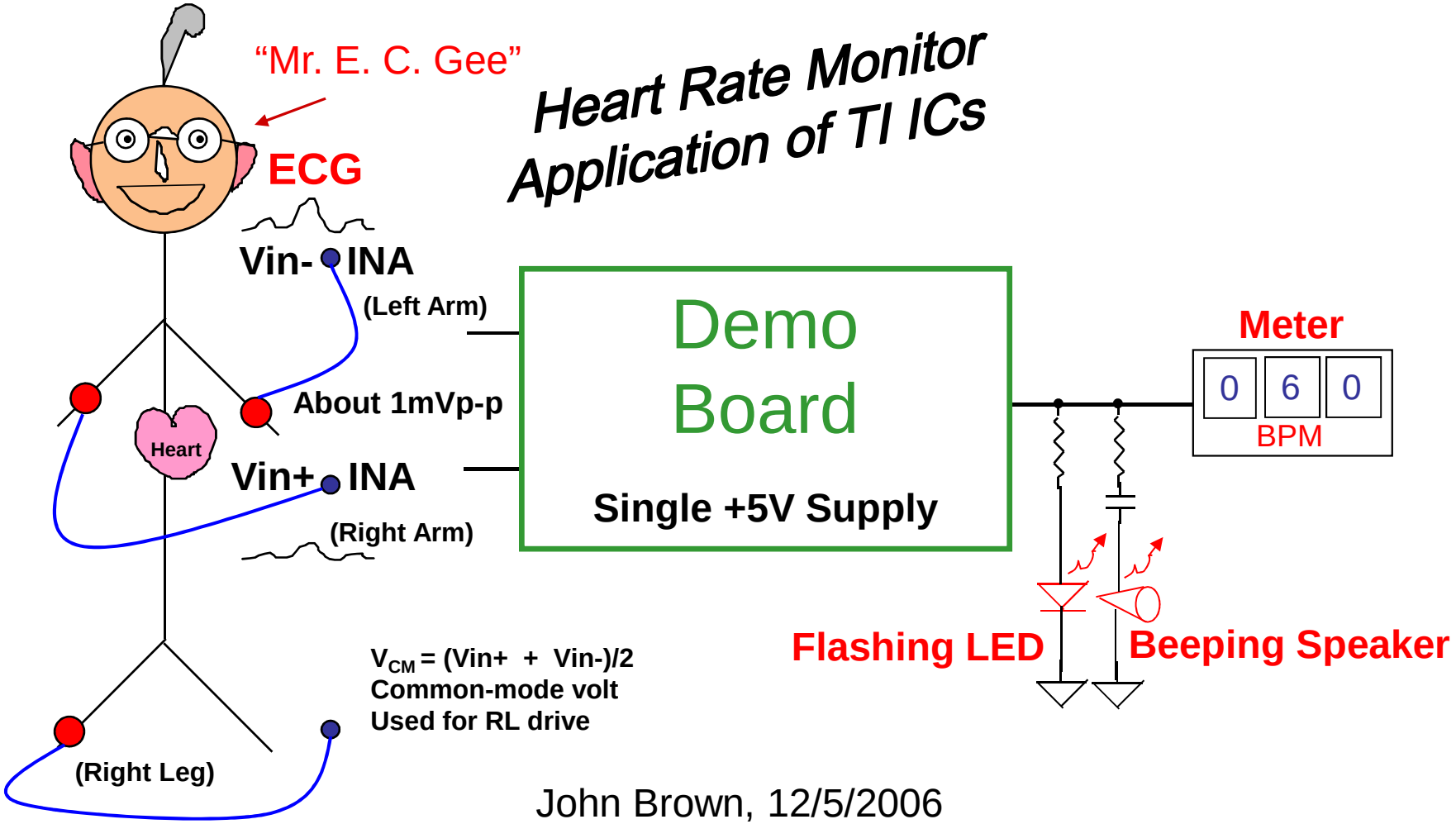
Baseline or dc Drift



WANDERING BASELINE

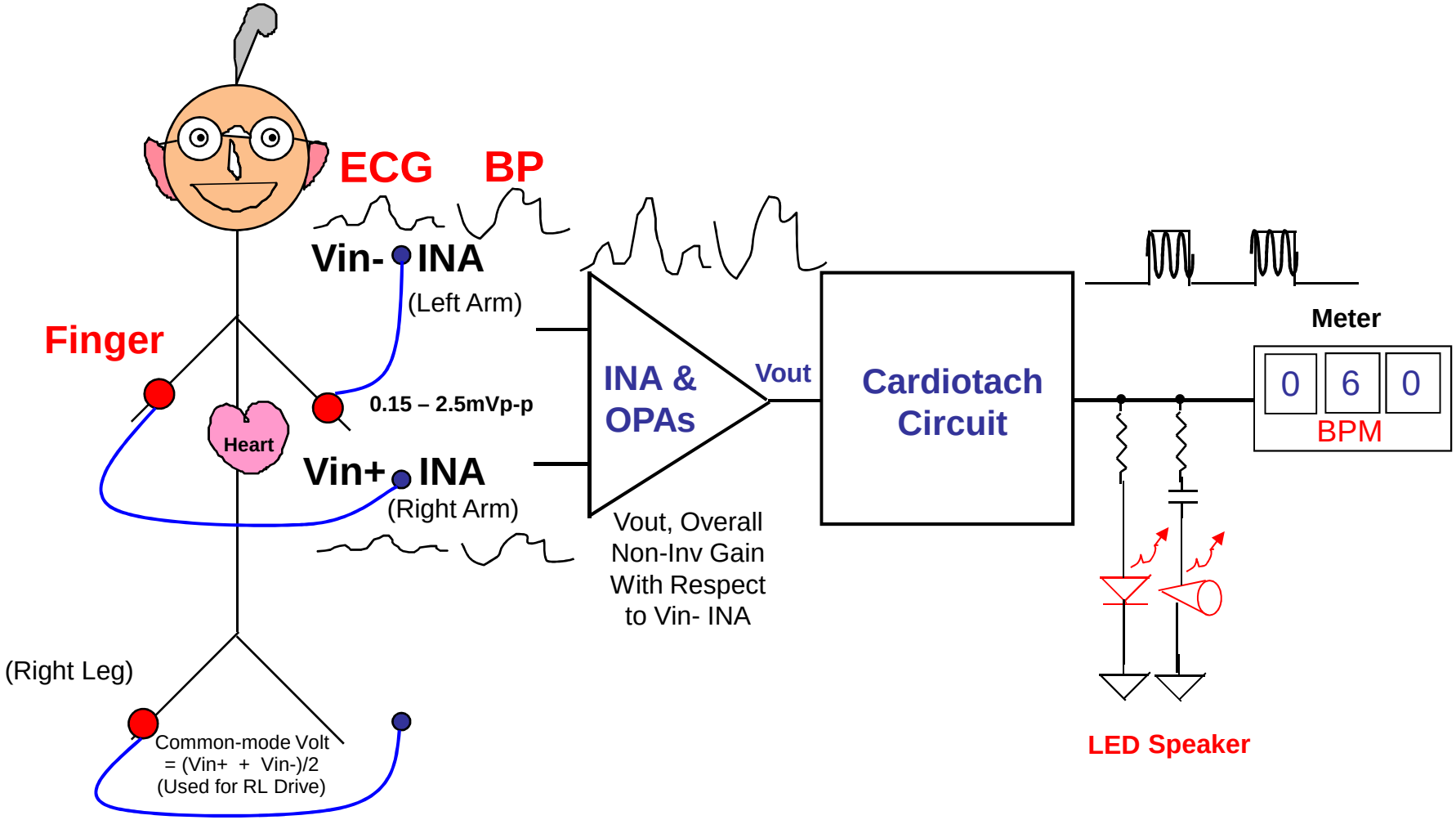
A Precision Low-Level DAS/ECG Cardiotachometer Demo Board

Can Also Be Used As Precision Low-Level Data Acquisition System Front-End



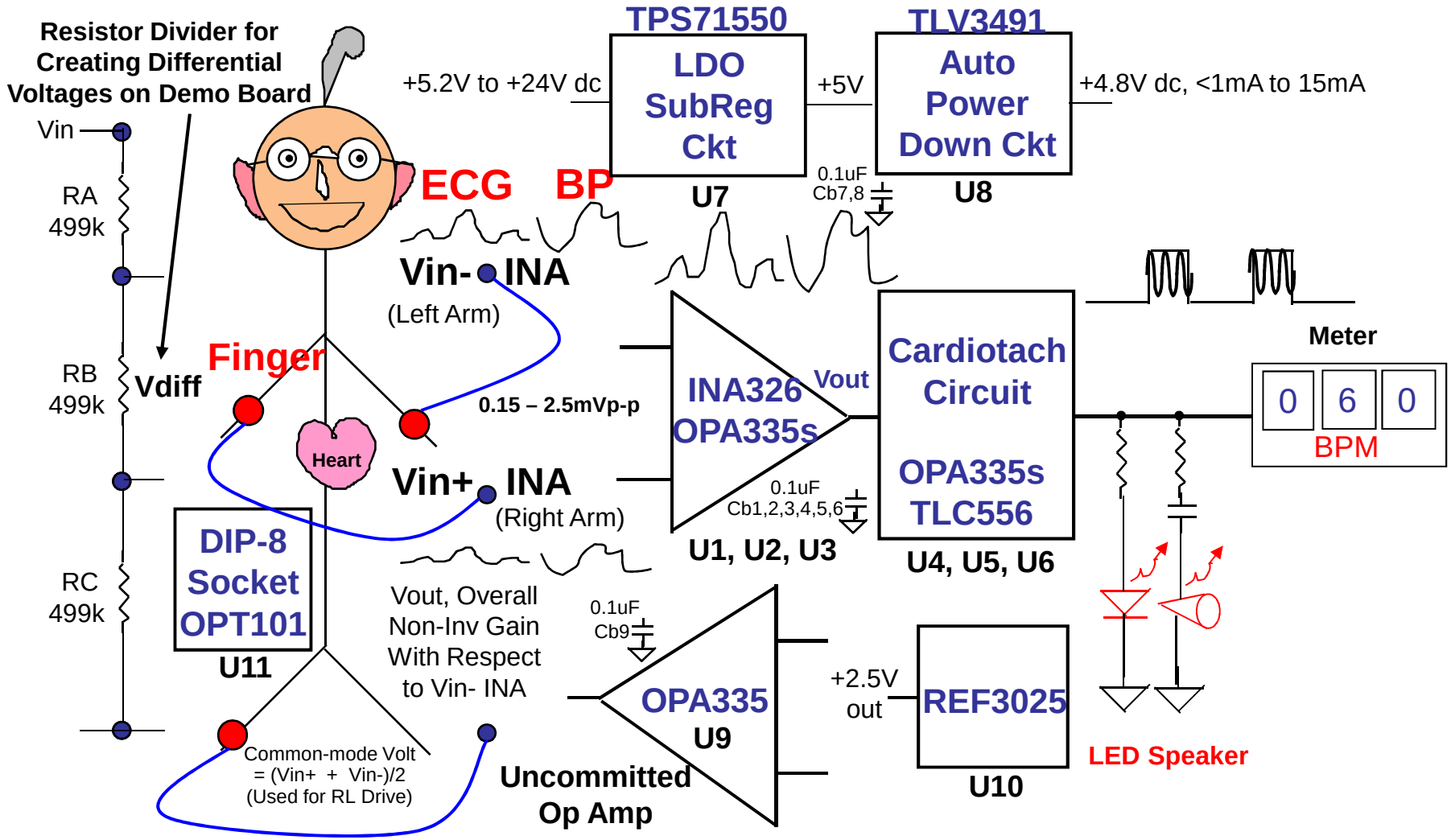
John Brown, 12/5/2006

A Precision Low-Level DAS/ECG Cardiotachometer Demo Board



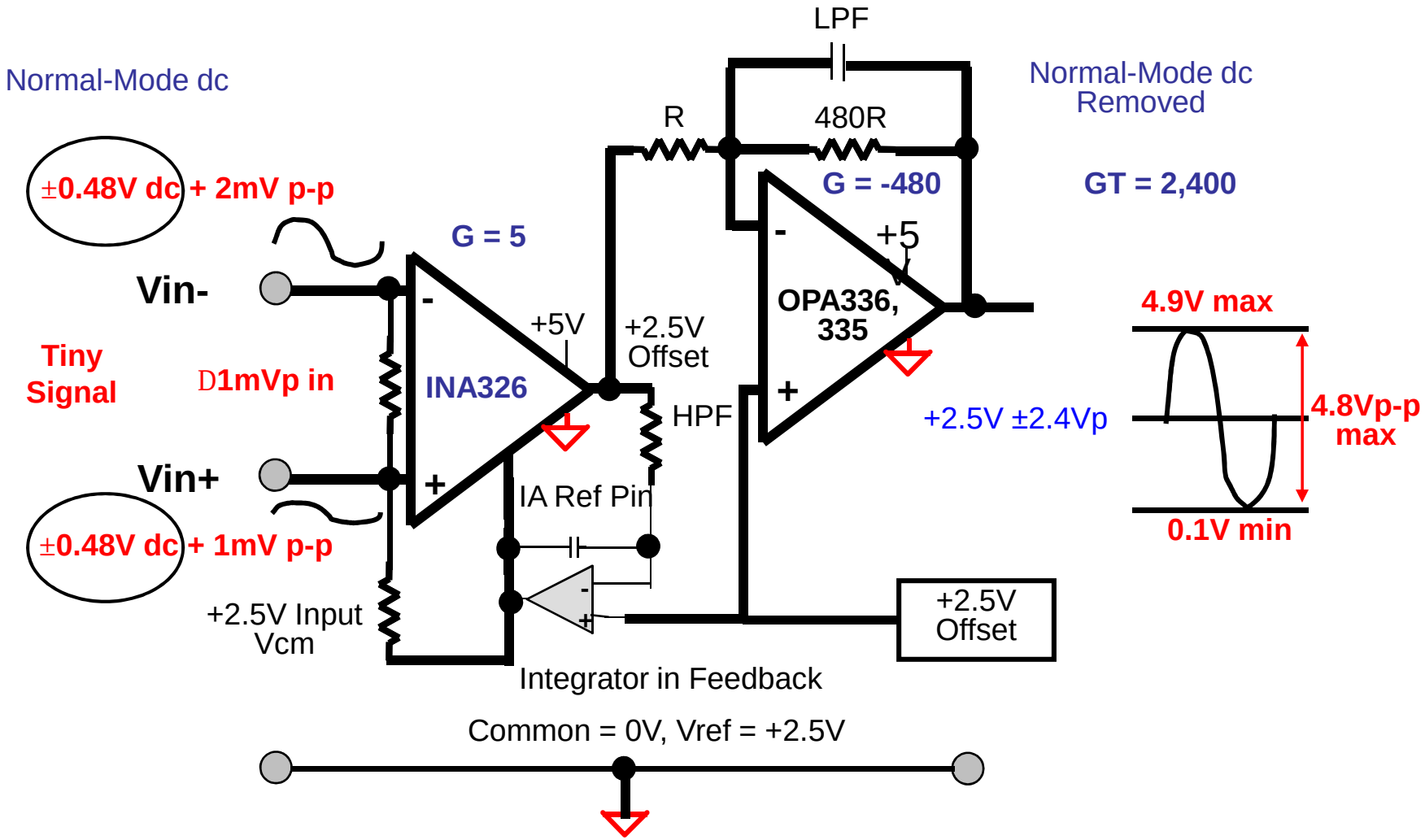
A Precision Low-Level DAS/ECG Cardiotachometer Demo Board

Uses 7 TI IC Types, 11 U's Total



A Precision Low-Level DAS/ECG Cardiotachometer Demo Board

AC-coupled input stage



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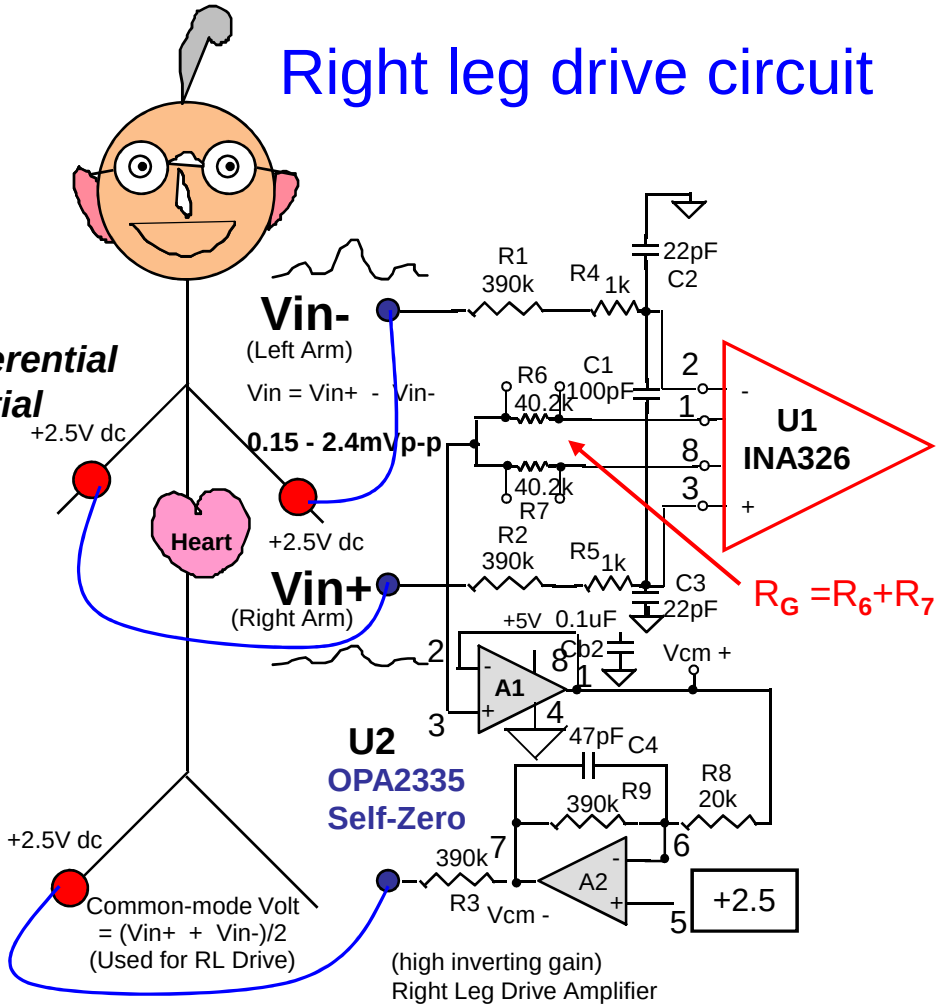
Right leg drive circuit



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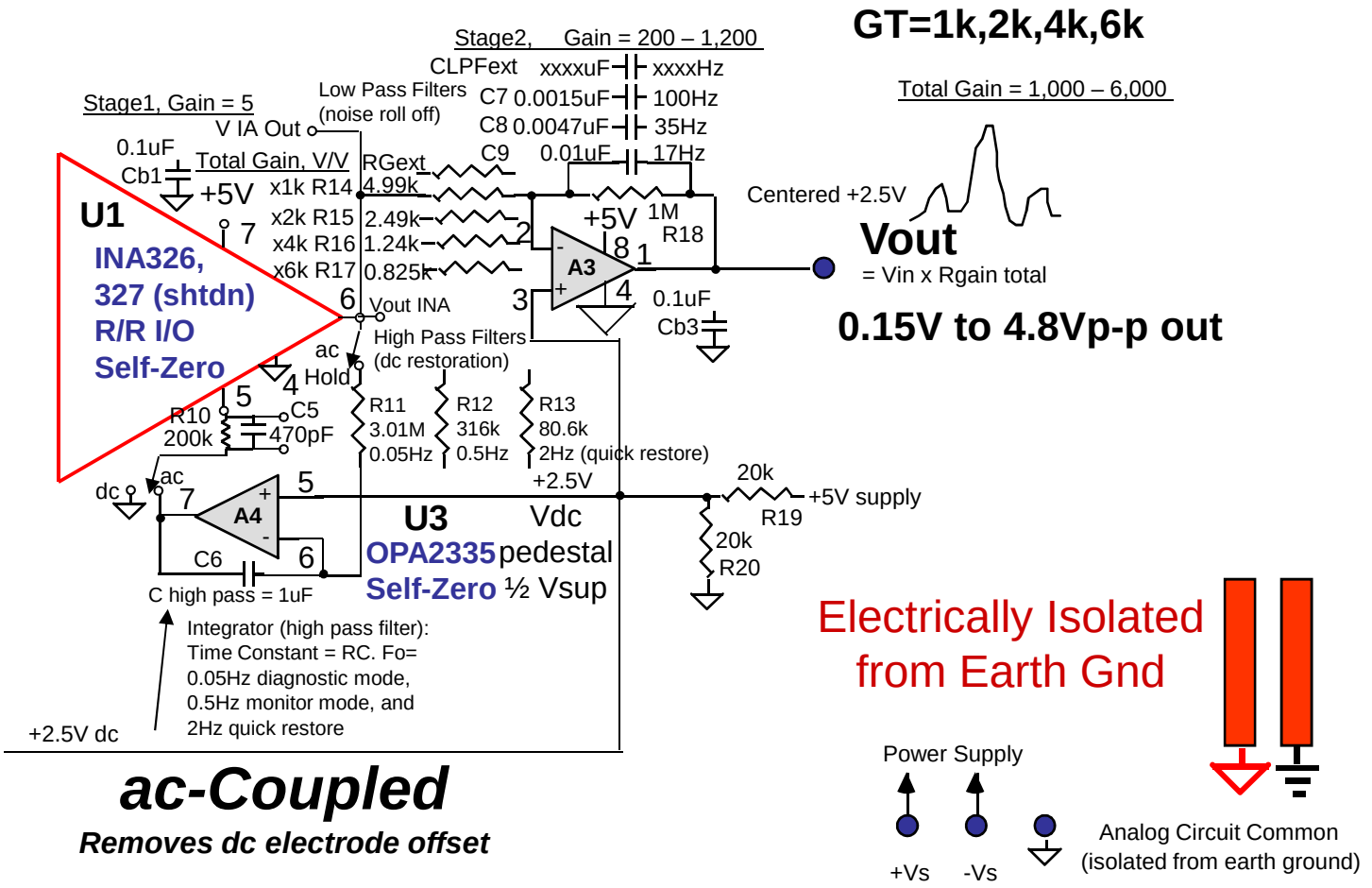
CMOS +5V SINGLE SUPPLY, INA326/7 & OPA2335



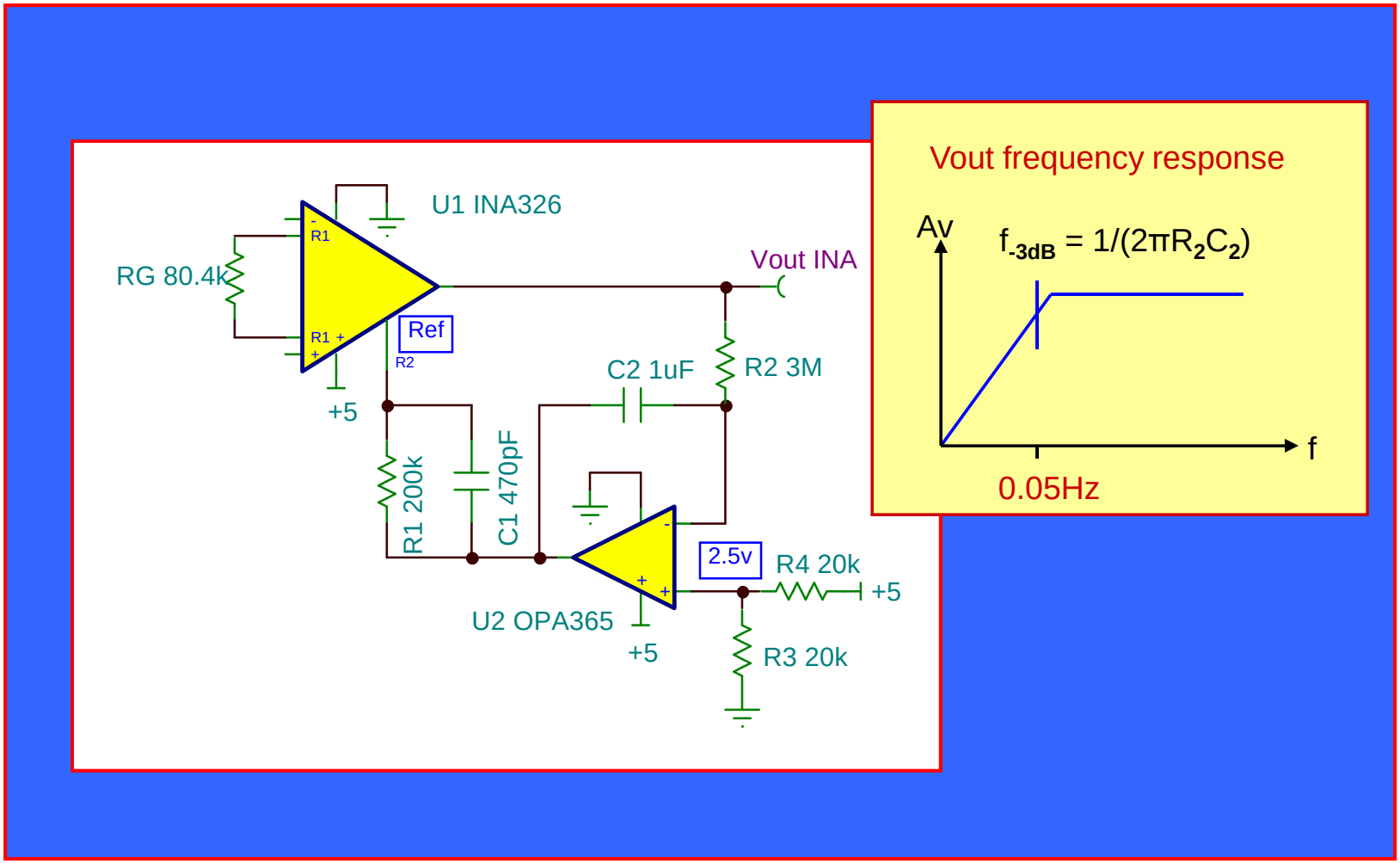
ac-Coupled

Removes dc electrode offset

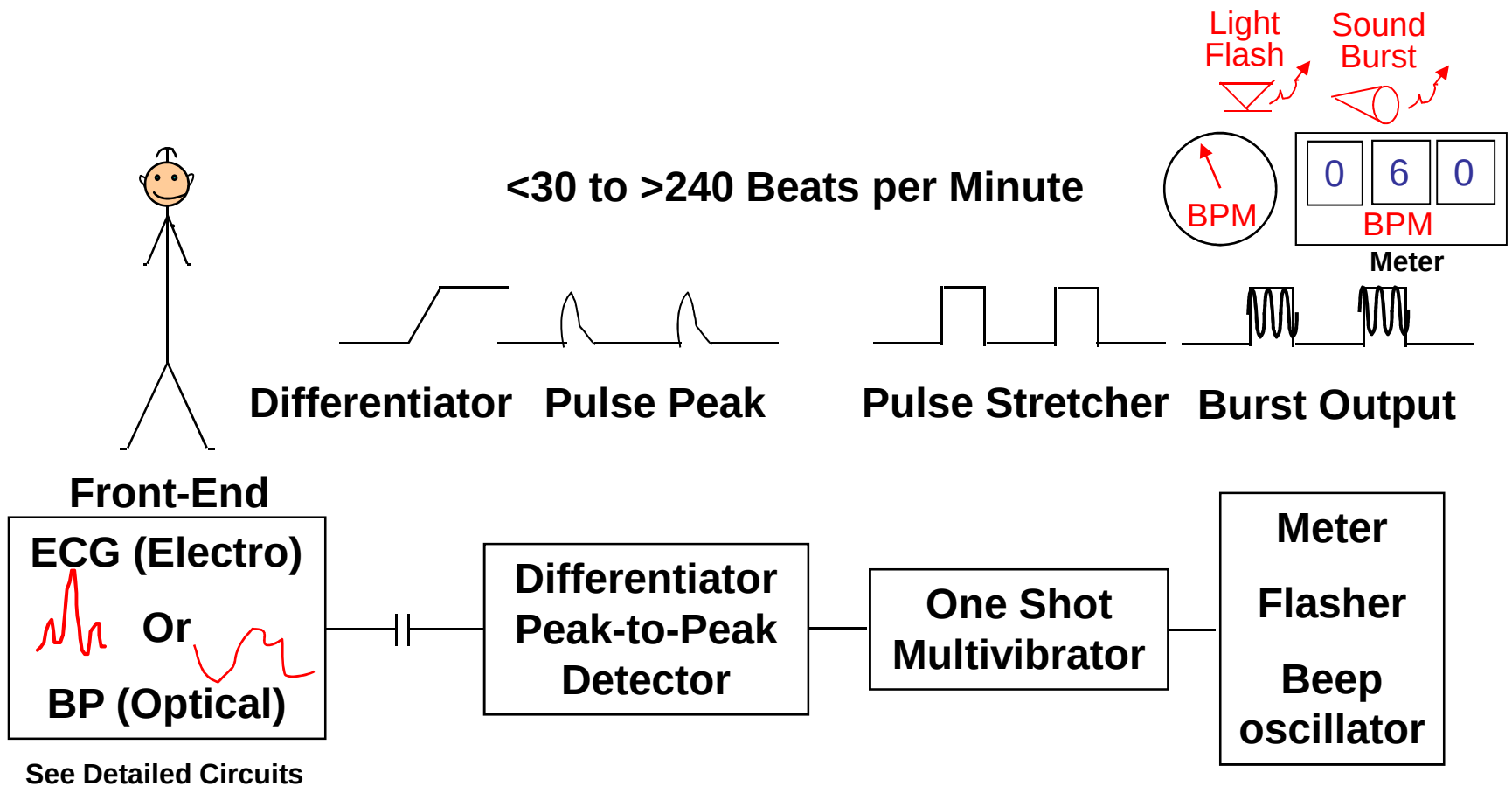
Electrically Isolated from Earth Gnd

A Precision Low-Level DAS/ECG Cardiotachometer Demo Board

DC restorer - removes electrode offset



A Precision Low-Level DAS/ECG Cardiotachometer Demo Board



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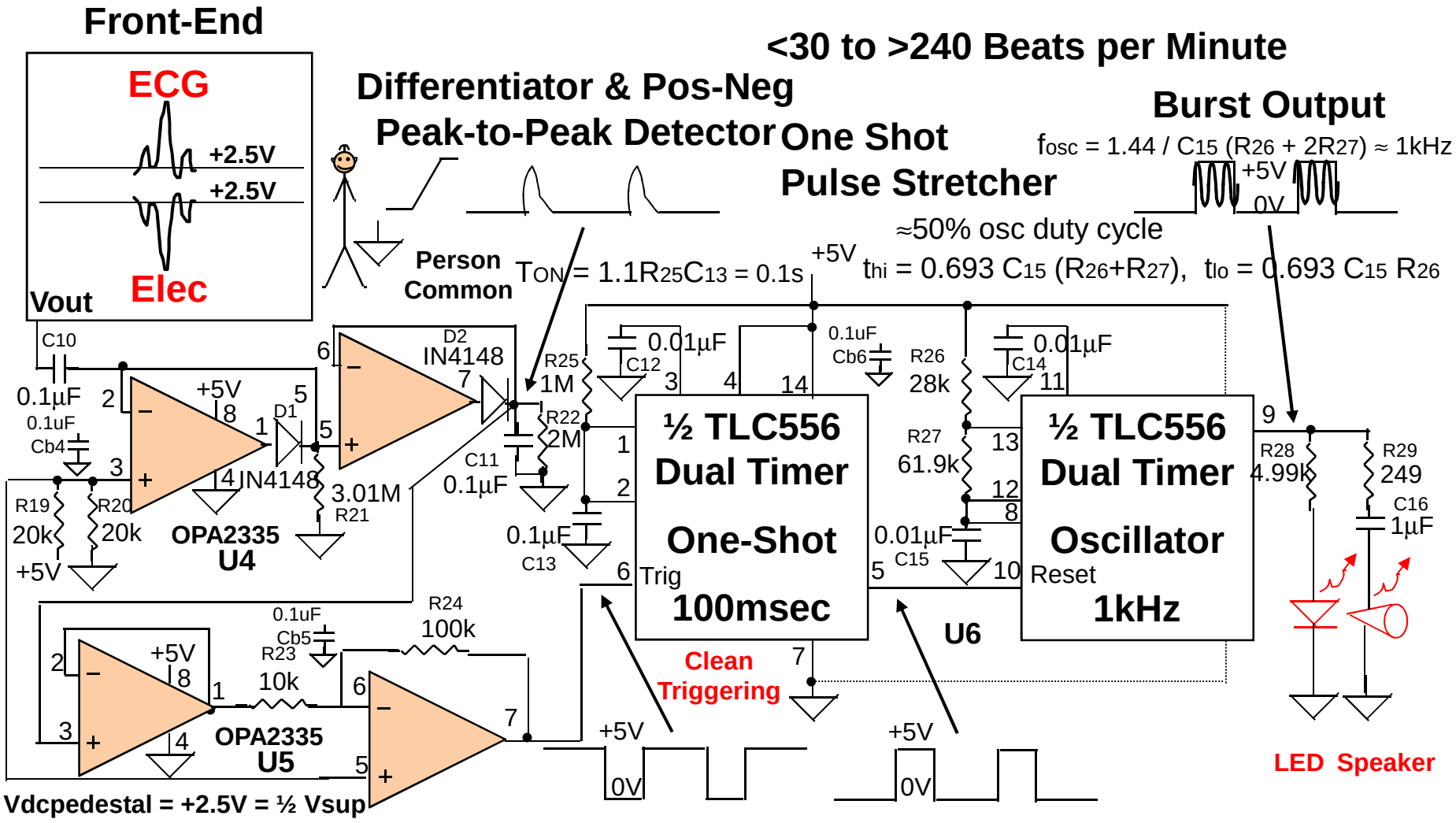
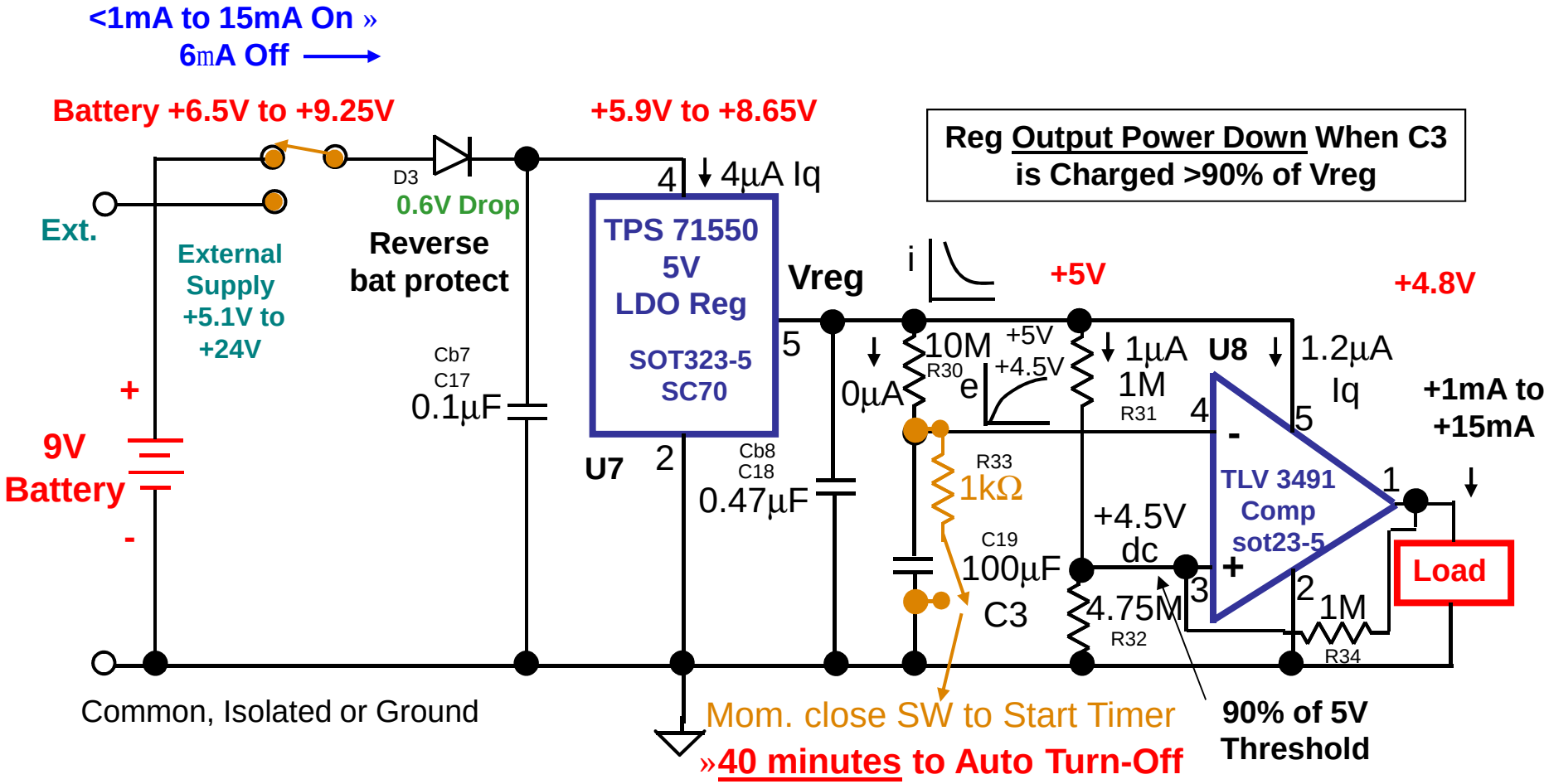
+5V Single Supply



A Precision Low-Level DAS/ECG Cardiotachometer Demo Board

Battery, Power Sub-Regulator and Auto Power Down Circuit



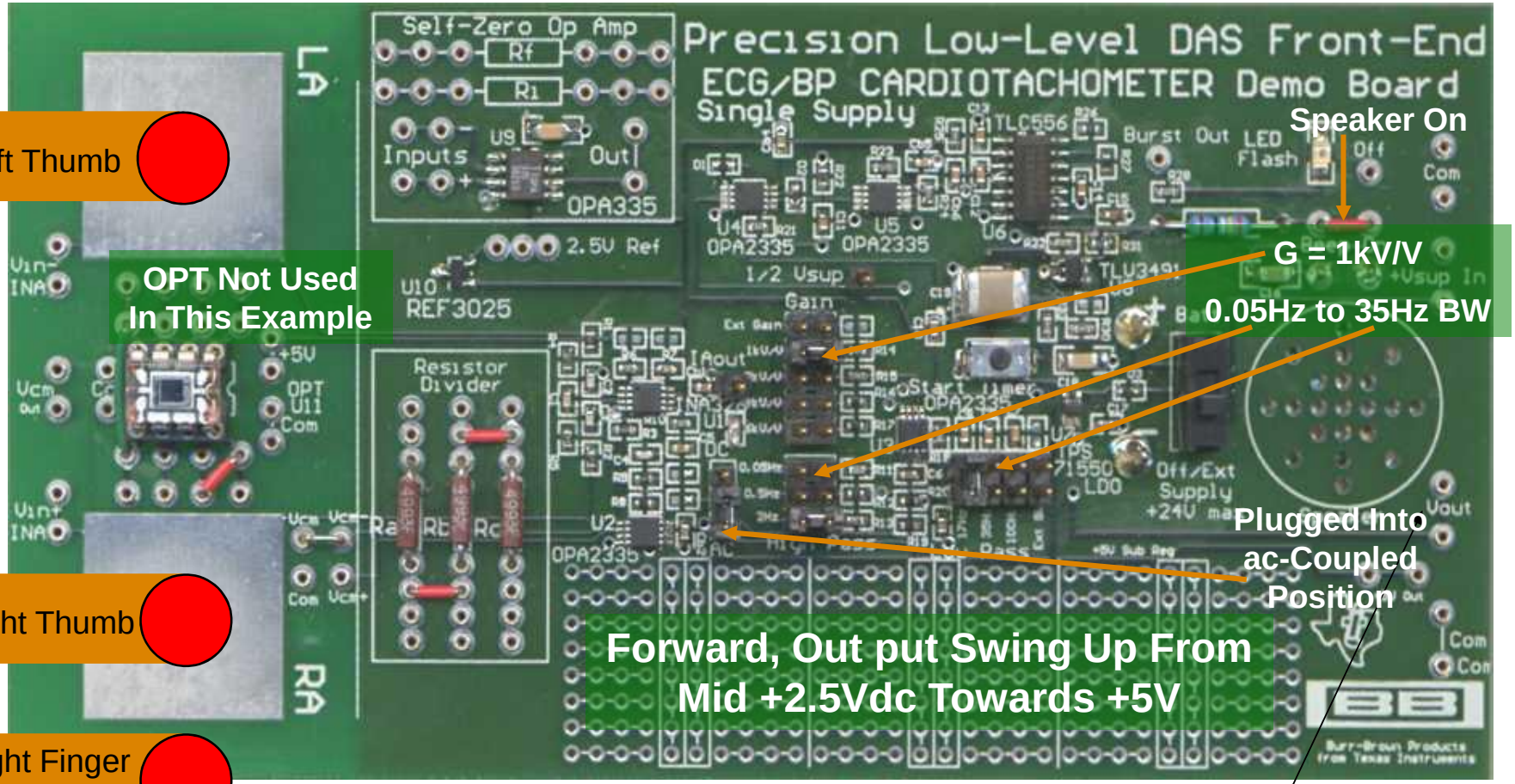
A Precision Low-Level DAS/ECG Cardiotachometer Demo Board

"Pin-Plug and Play" features

- Wires to pin-sockets, no soldering, plus plug selectable gain & BW
- Self contained ICs, resistors, capacitors, LED, speaker, switches
- Battery operated (+9V included) or external supply up to 24V max with auto-sleep
- Adjustable gain & BW (Separate LPF & HPF), differential or single-ended inputs, ac or dc coupled
- Breadboard area for additional circuits

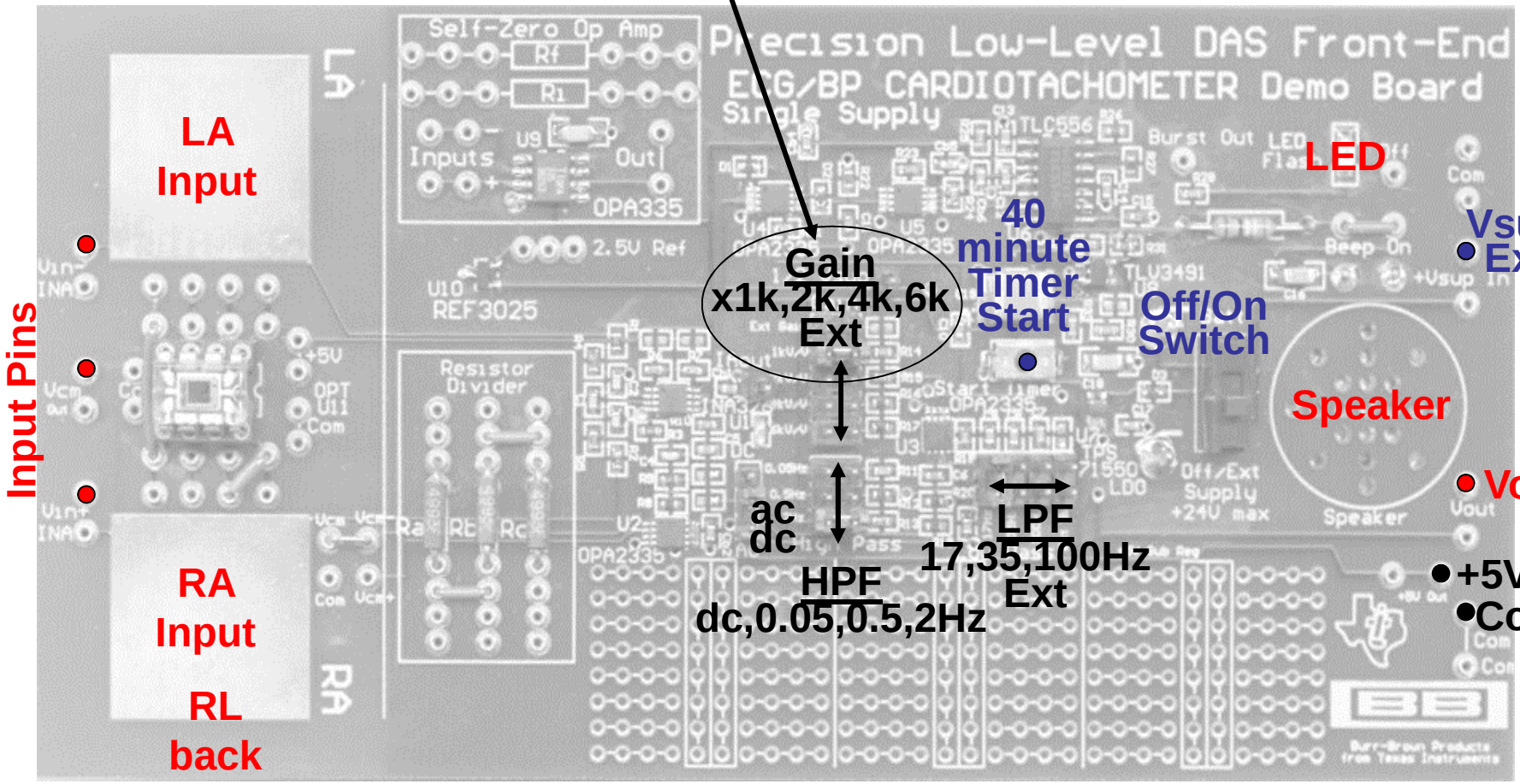
A Precision Low-Level DAS/ECG Cardiotachometer Demo Board – top side

Can Hold Right Side of Board Against Table to Steady Skin-Electrode Contact

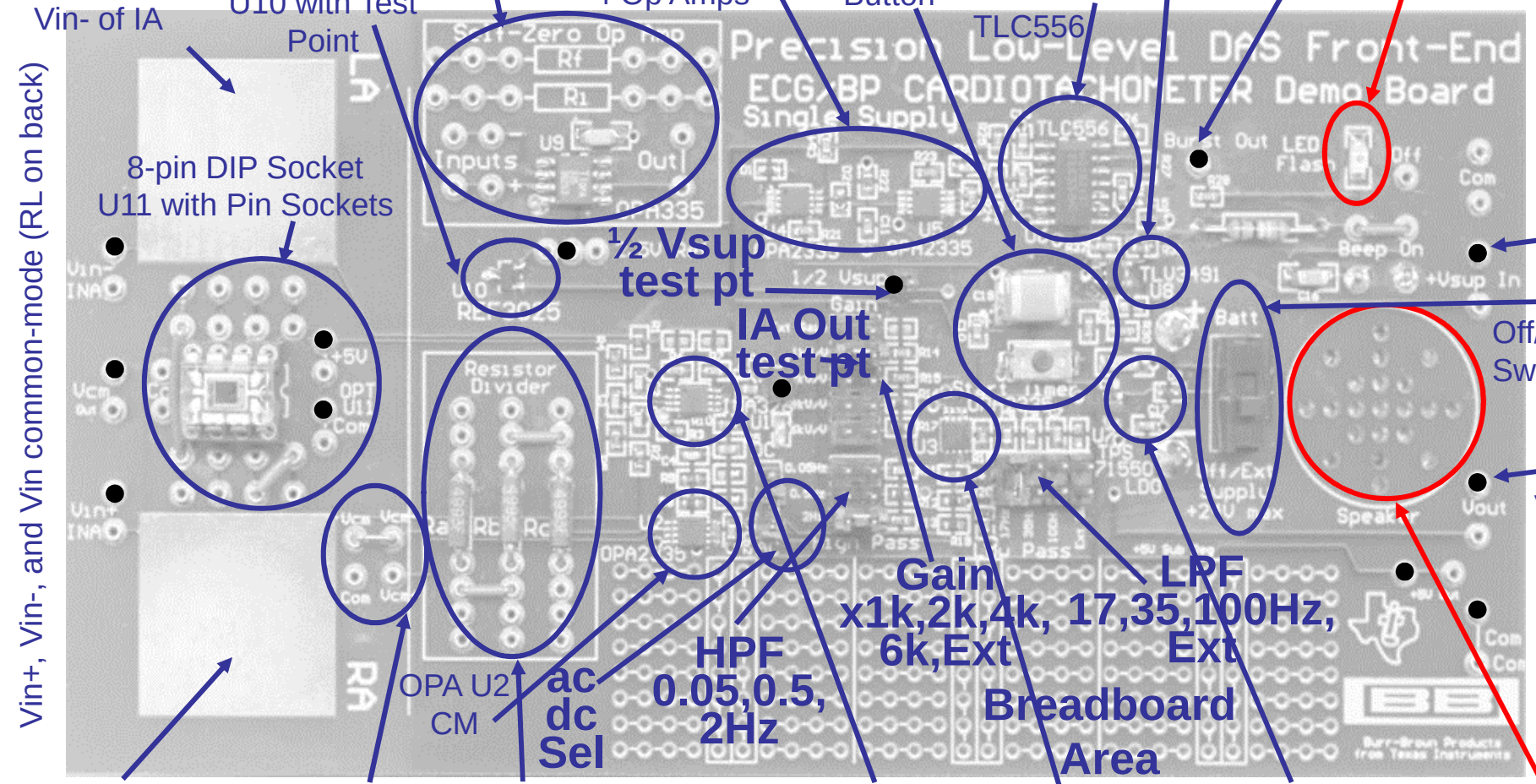


A Precision Low-Level DAS/ECG Cardiotachometer Demo Board – top side

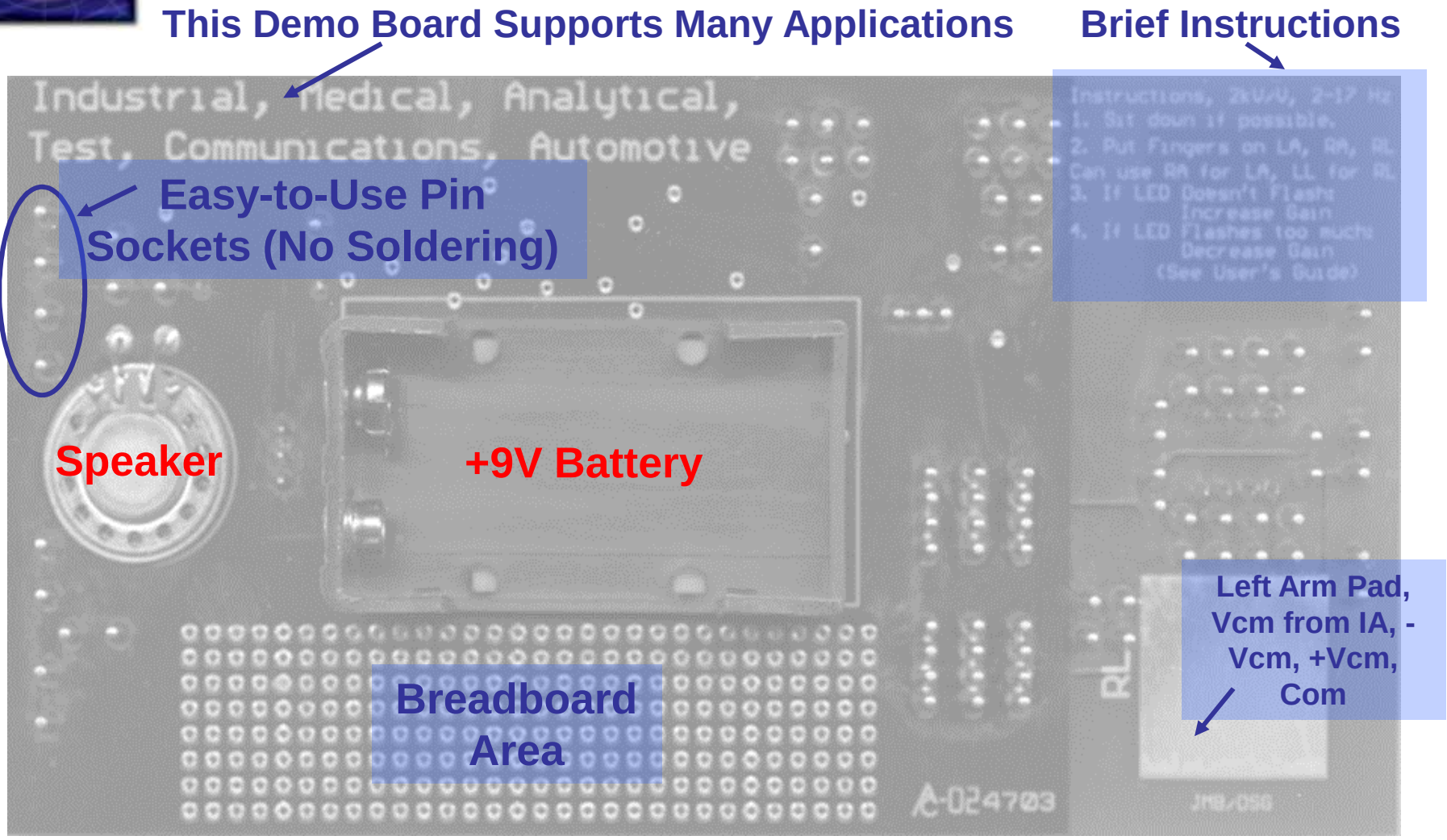
Gain Control, Selected By Changing Shorting Bar Position



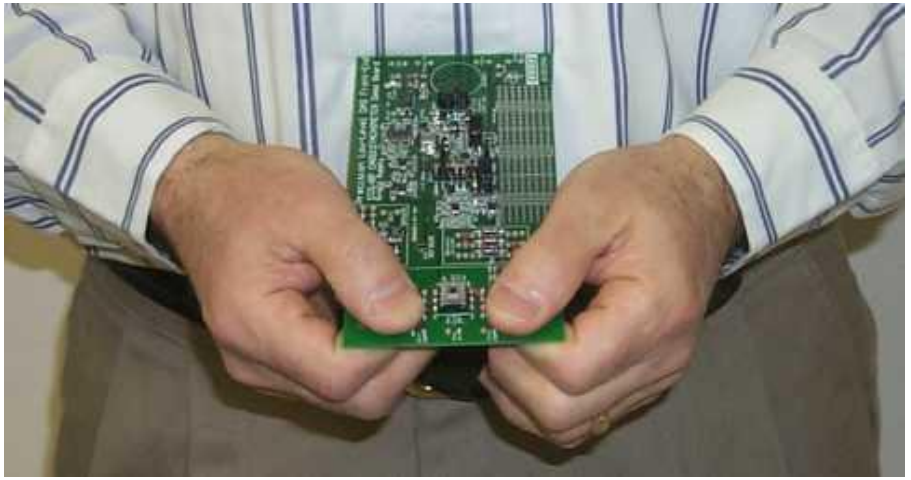
A Precision Low-Level DAS/ECG Cardiotachometer Demo Board – top side



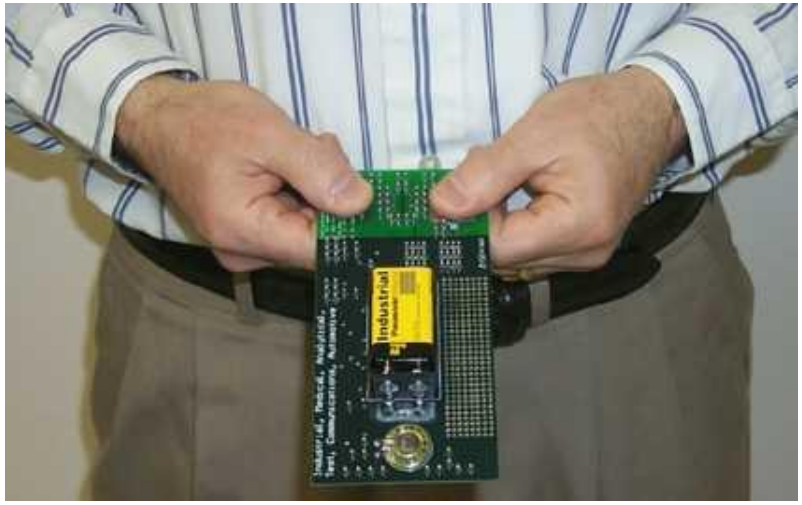
A Precision Low-Level DAS/ECG Cardiotachometer Demo Board – back side

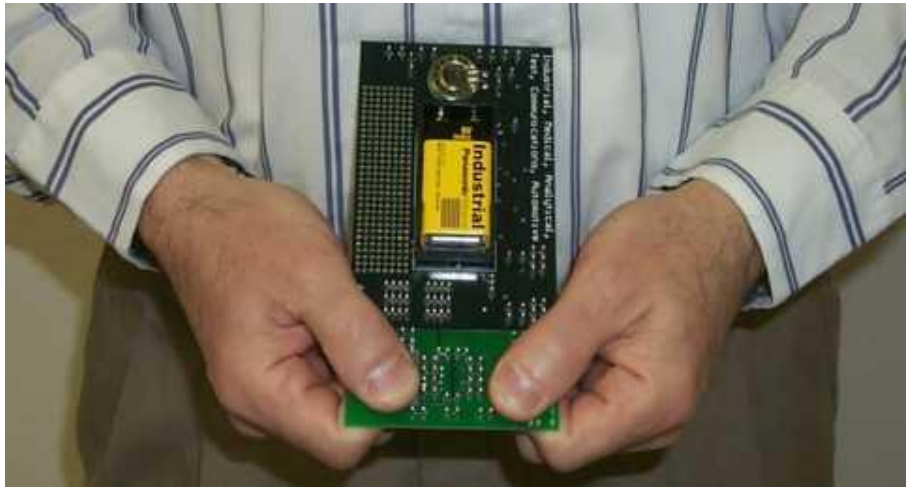


Low-Level DAS / ECG Cardiotachometer Demo Board - Standing



Gently Hold Electrode Pad Areas (relax fingers), Standing can be ok. Sit Down if Possible



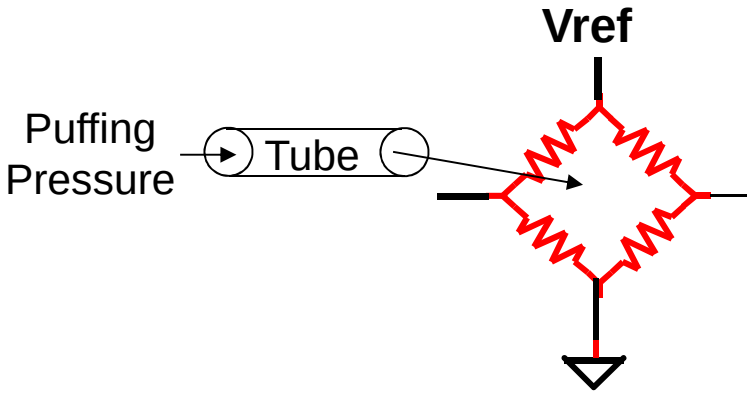


A Precision Low-Level DAS/ECG Cardiotachometer Demo Board

Additional Applications

- Industrial pressure, temperature flow and humidity and general sensor signal conditioning
- Medical diagnostic and biophysical monitoring
- Analytical and scientific instrumentation
- Communications sensor and signal amplification
- Automotive sensors

A Precision Low-Level DAS/ECG Cardiotachometer Demo Board



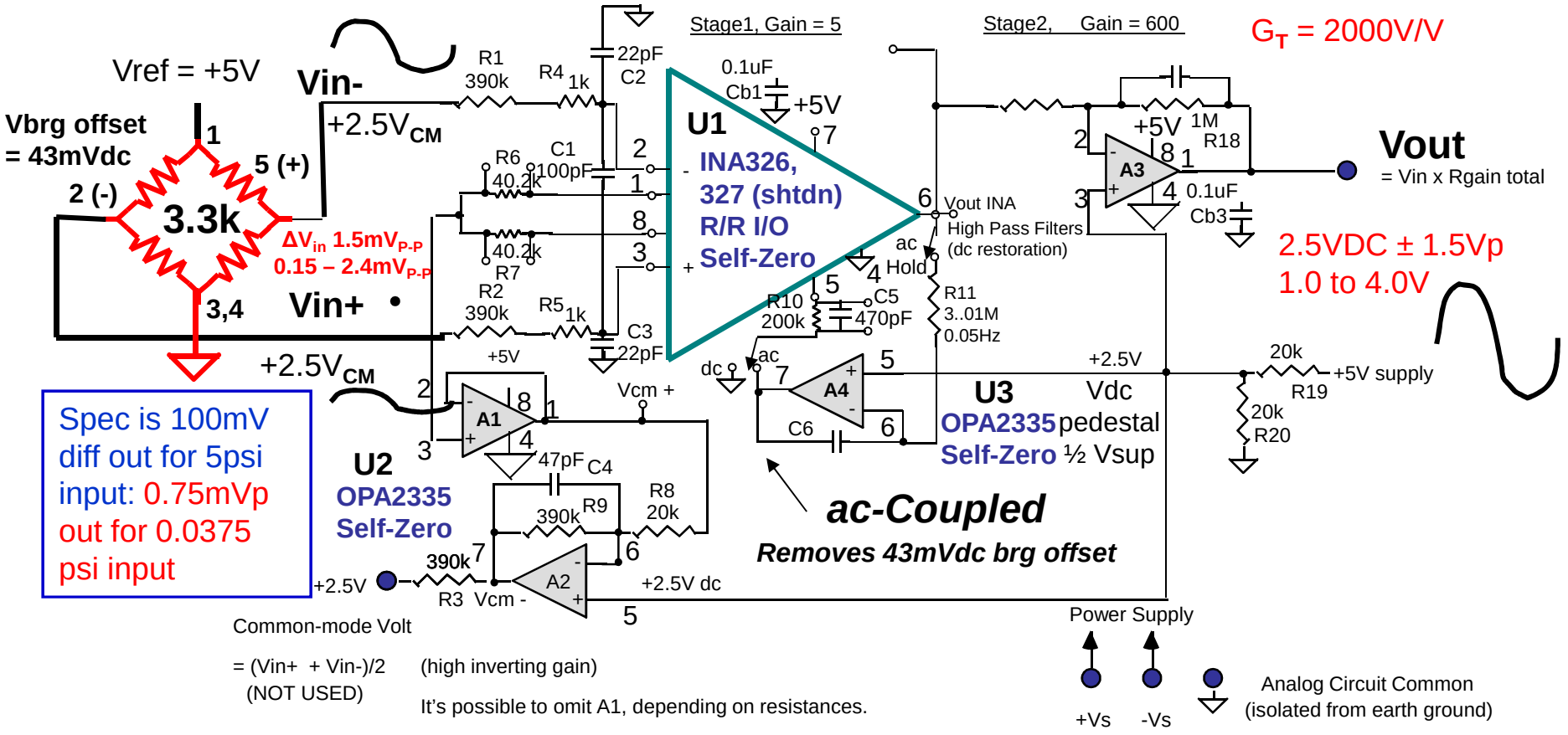
Pressure Bridge Application

Quickly Puffing on Tube

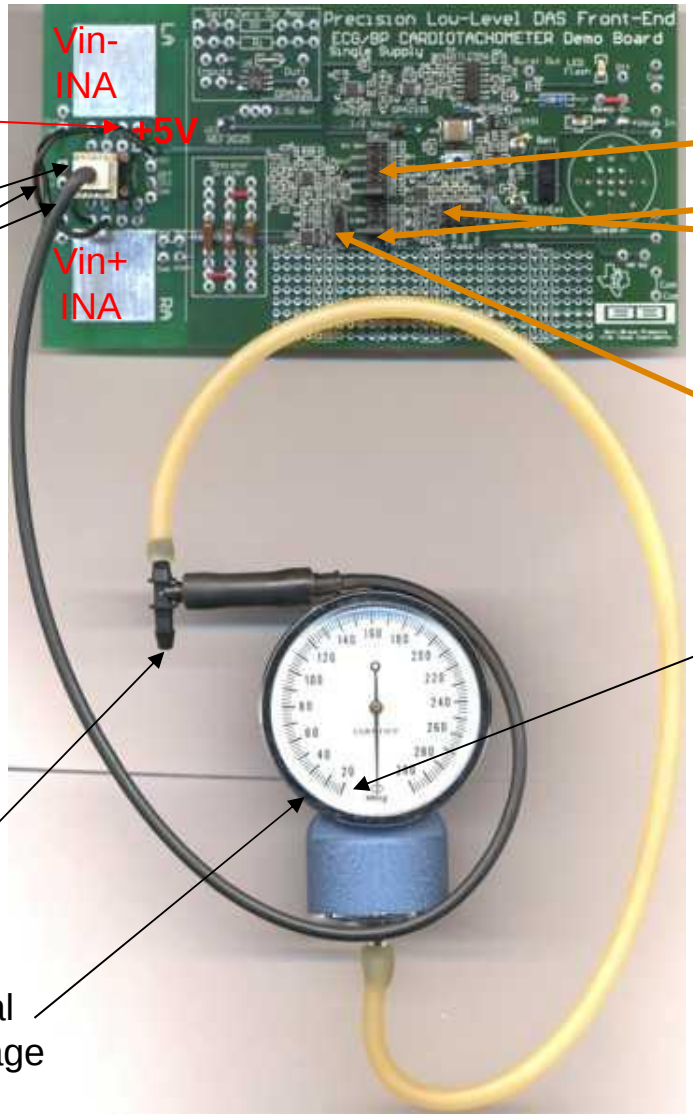
ac-Coupled

Low-Level DAS / ECG Cardiotachometer Demo Board – Puffing Pressure Bridge

Silicon Microstructurers Inc.
Milpitas, CA, Press Bridge
SSM5410-005-G-P
408-577-0100



Low-Level DAS / ECG Cardiotachometer Demo Board – Puffing Pressure Bridge



+5V Excitation Directly From Sub Regulated Supply

Pressure Bridge

NOTE – Same Phase
- Bridge (2) Out => Vin+ INA
+ Bridge (5) Out => Vin- INA
Makes Vout Have Same Phase as Vin diff That is Vout 2nd Stage Increases When Vin- INA Increases With Respect to Vin+ INA

Gtotal = 2kV/V

2Hz to

17Hz BW

Plugged Into ac-Coupled Position

Δ5mmHg, Δ0.0375psi Change When Puffing

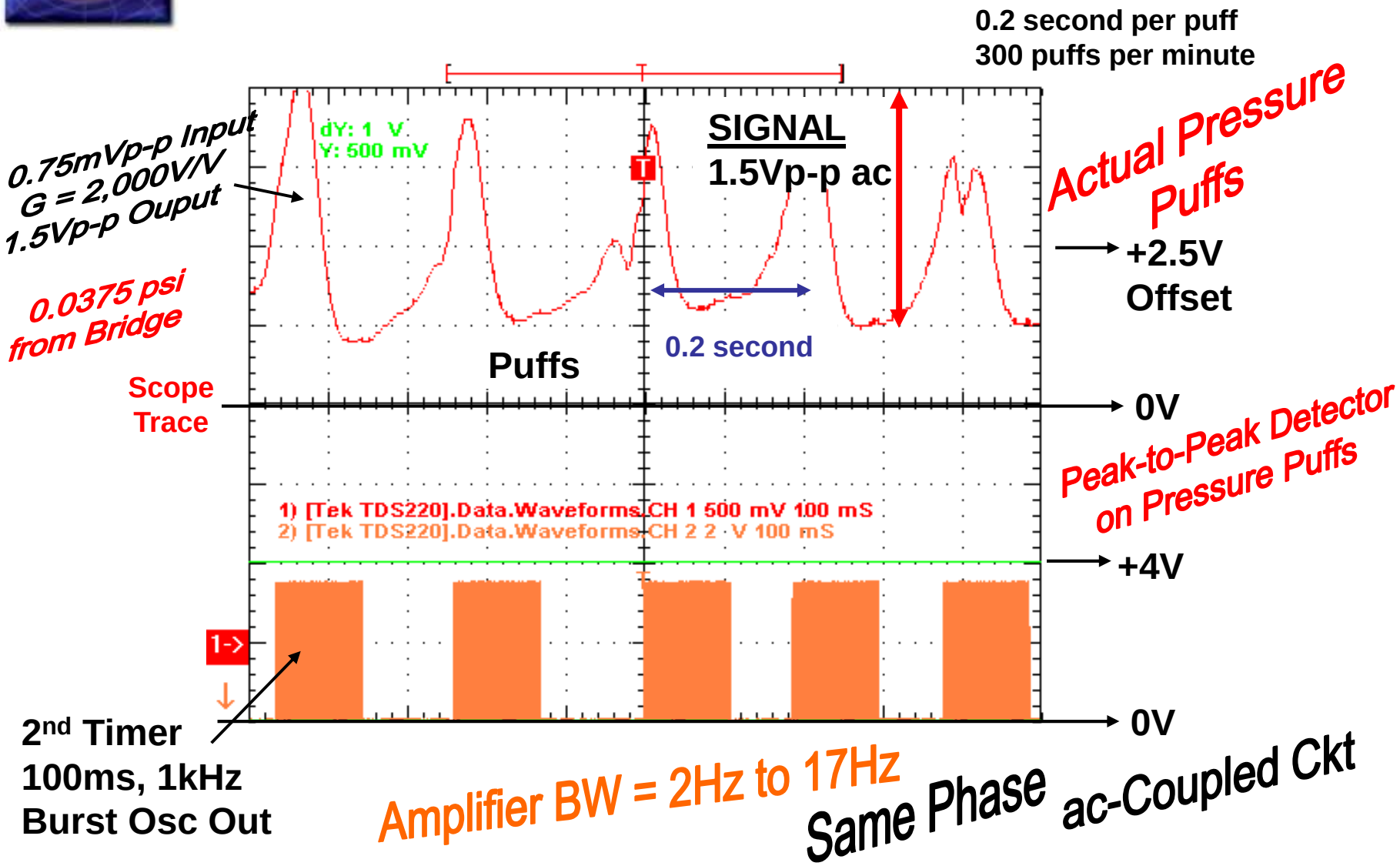
Puffing Pressure Input

Mechanical Pressure Gage

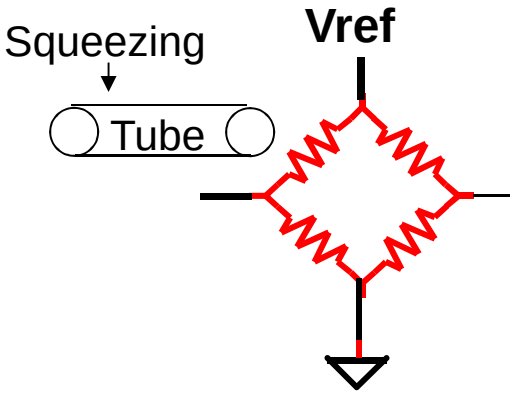
ac-Coupled

Same Phase

Low-Level DAS / ECG Cardiotachometer Demo Board – Puffing Pressure Bridge



A Precision Low-Level DAS/ECG Cardiotachometer Demo Board



Circuit Uses OPA336s
Instead of OPA335s

Pressure Bridge Application

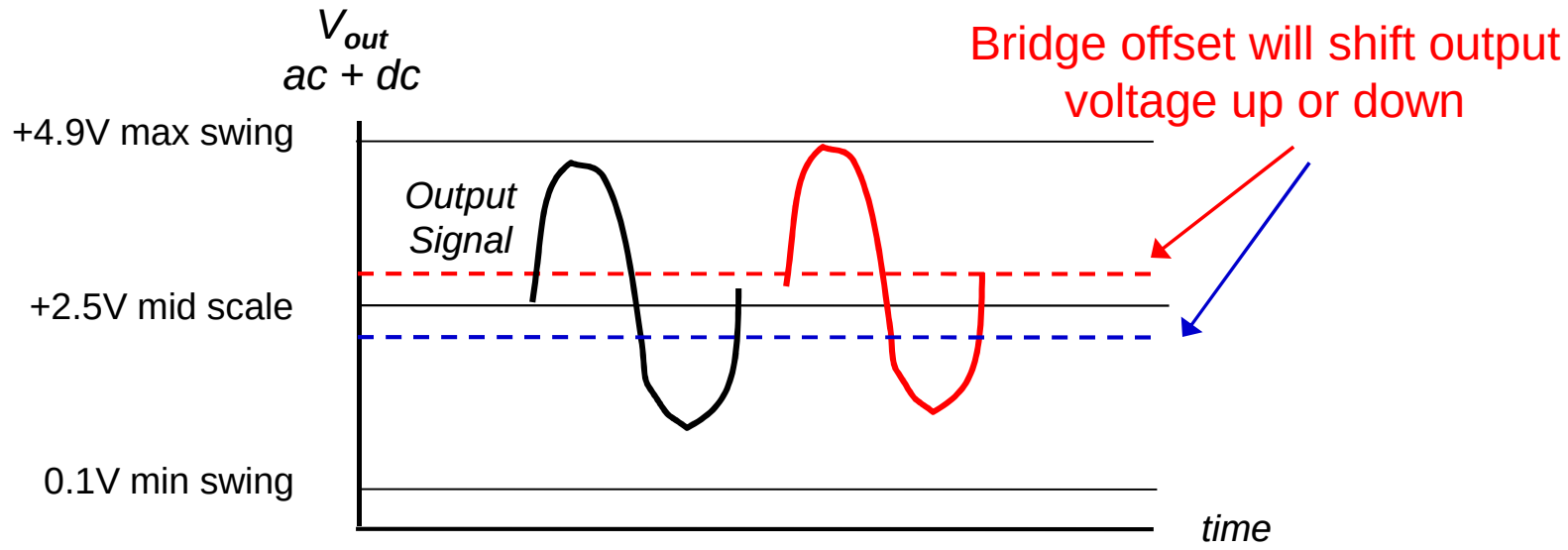
Slowly Squeezing on Tube

dc-Coupled

A Precision Low-Level DAS/ECG Cardiotachometer Demo Board

dc-coupled

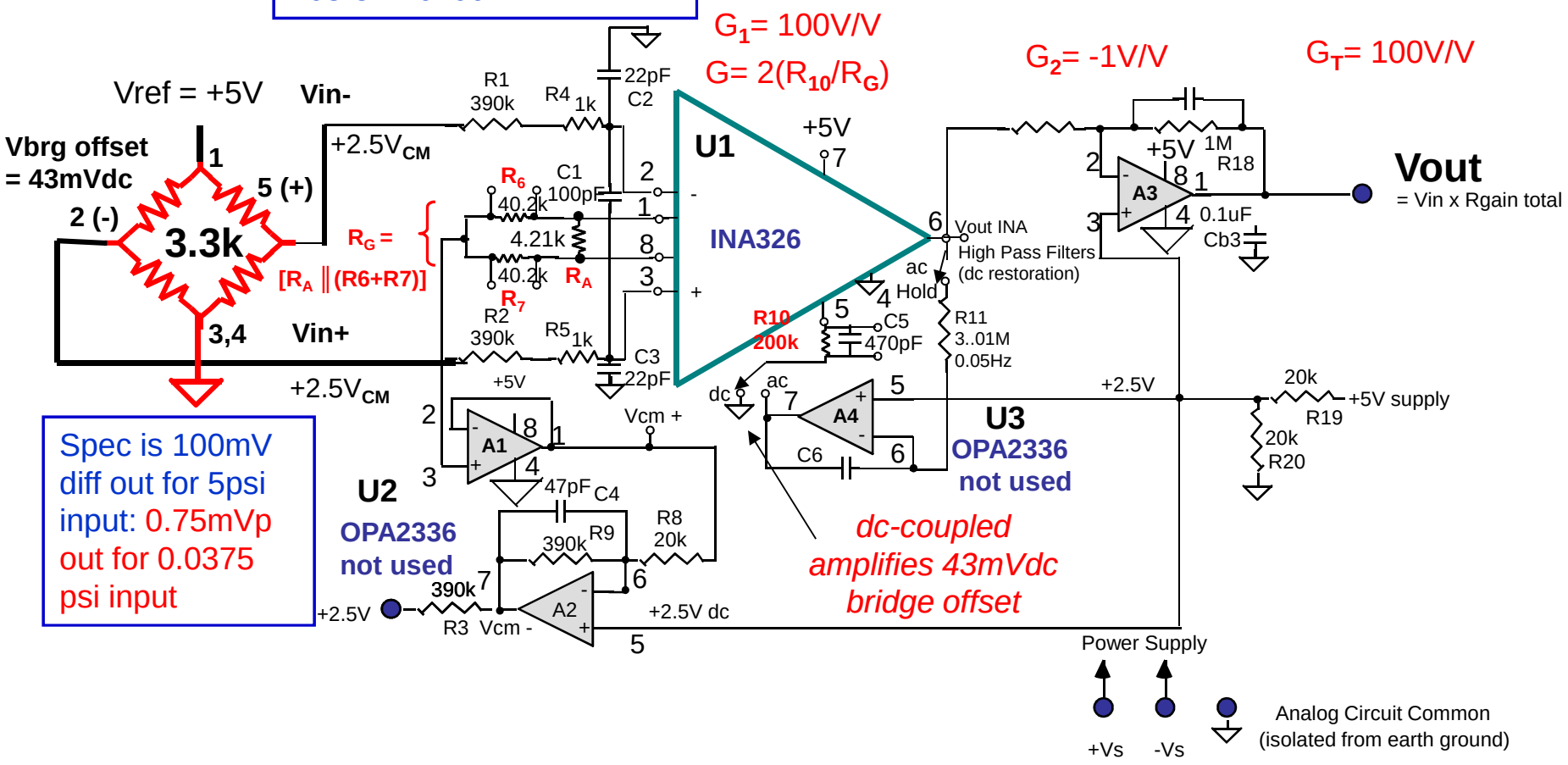
dc bridge offset (Normal-Mode voltage) is not removed



In single supply circuits, a mid-scale offset is used with the amplifiers to assure linear operation.

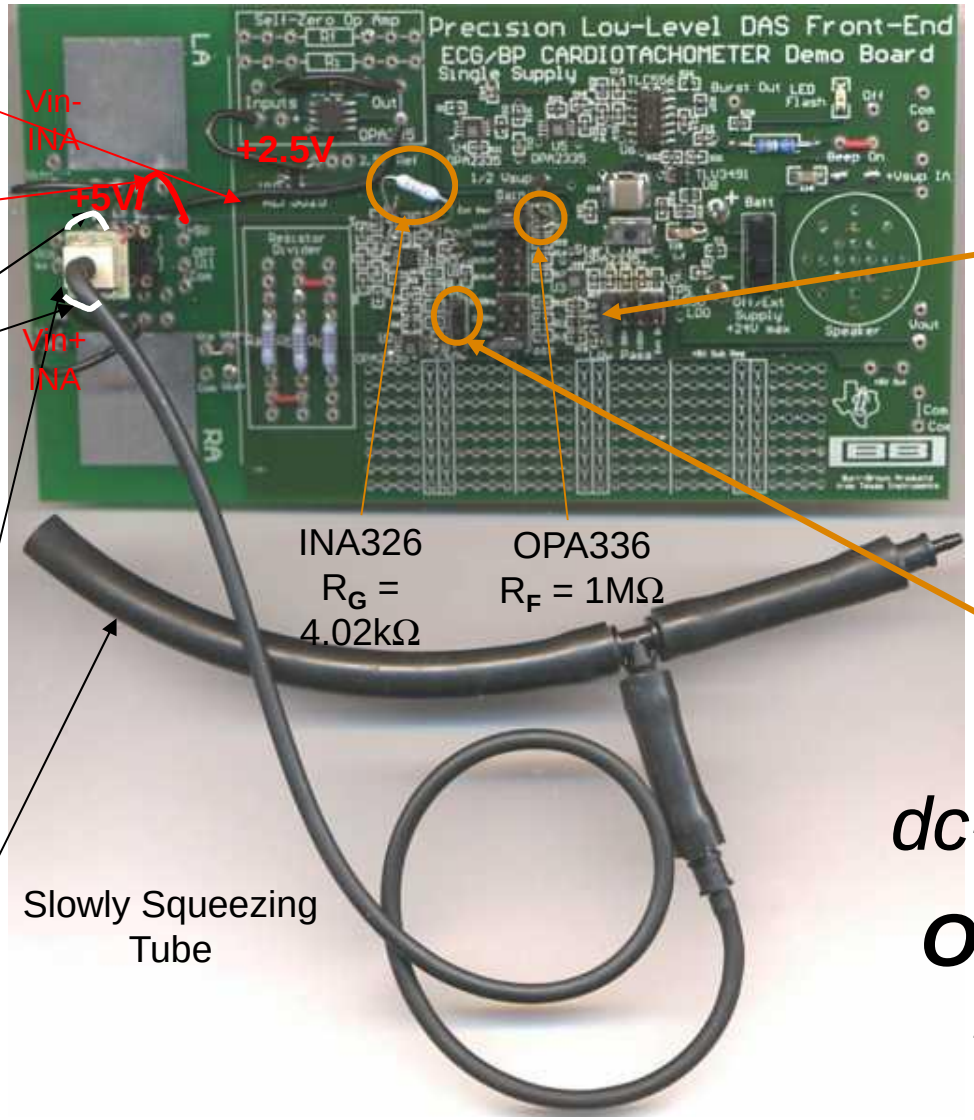
Low-Level DAS / ECG Cardiotachometer Demo Board – Squeezing Pressure Bridge

Silicon Microstructurers Inc.
Milpitas, CA, Press Bridge
SSM5410-005-G-P
408-577-0100



Spec is 100mV diff out for 5psi input: 0.75mVp out for 0.0375 psi input

Low-Level DAS / ECG Cardiotachometer Demo Board – Squeezing Pressure Bridge



#2, +2.5V Excitation Buffered Through Op amp Or

#1, +5V Excitation Directly From Sub Regulated Supply

NOTE – Opposite Phase
+ Bridge (5) Out => Vin+ INA
- Bridge (2) Out => Vin- INA
Makes Vout Have Opposite Phase as Vin diff That is Vout 2nd Stage Decreases When Vin+ INA Increases With Respect to Vin- INA

Pressure Bridge

Pressure Tubing T-Connection

Slowly Squeezing Tube

Gtotal = 100V/V dc

17Hz BW

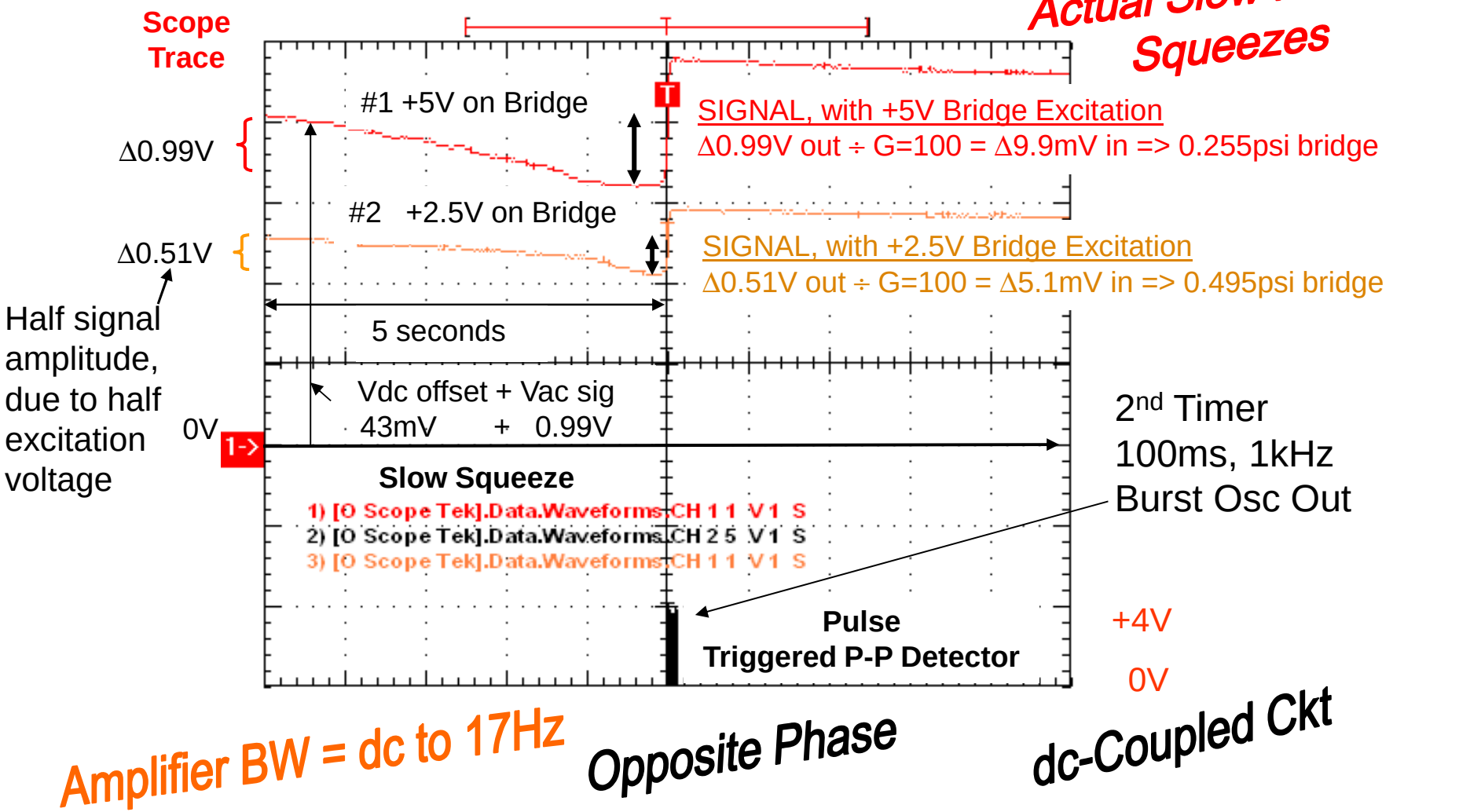
Circuit Uses OPA336s Instead of OPA335s for Op Amps

Plugged Into dc-Coupled Position

dc-Coupled

Opposite Phase

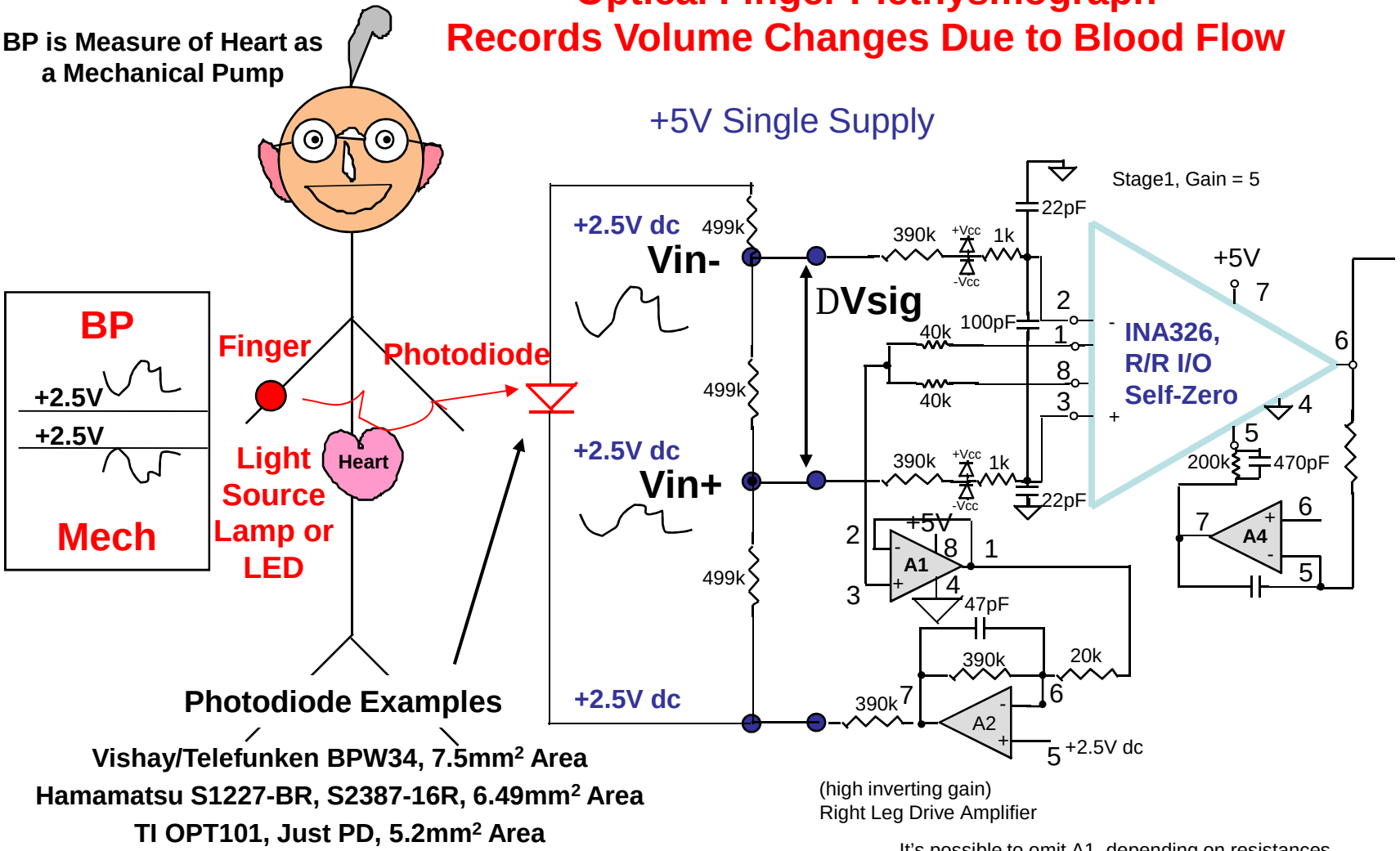
Low-Level DAS / ECG Cardiotachometer Demo Board – Squeezing Pressure Bridge



A Precision Low-Level DAS/ECG Cardiotachometer Demo Board - Optical Relative Blood Pressure Monitor

Optical Finger Plethysmograph
Records Volume Changes Due to Blood Flow

BP is Measure of Heart as a Mechanical Pump

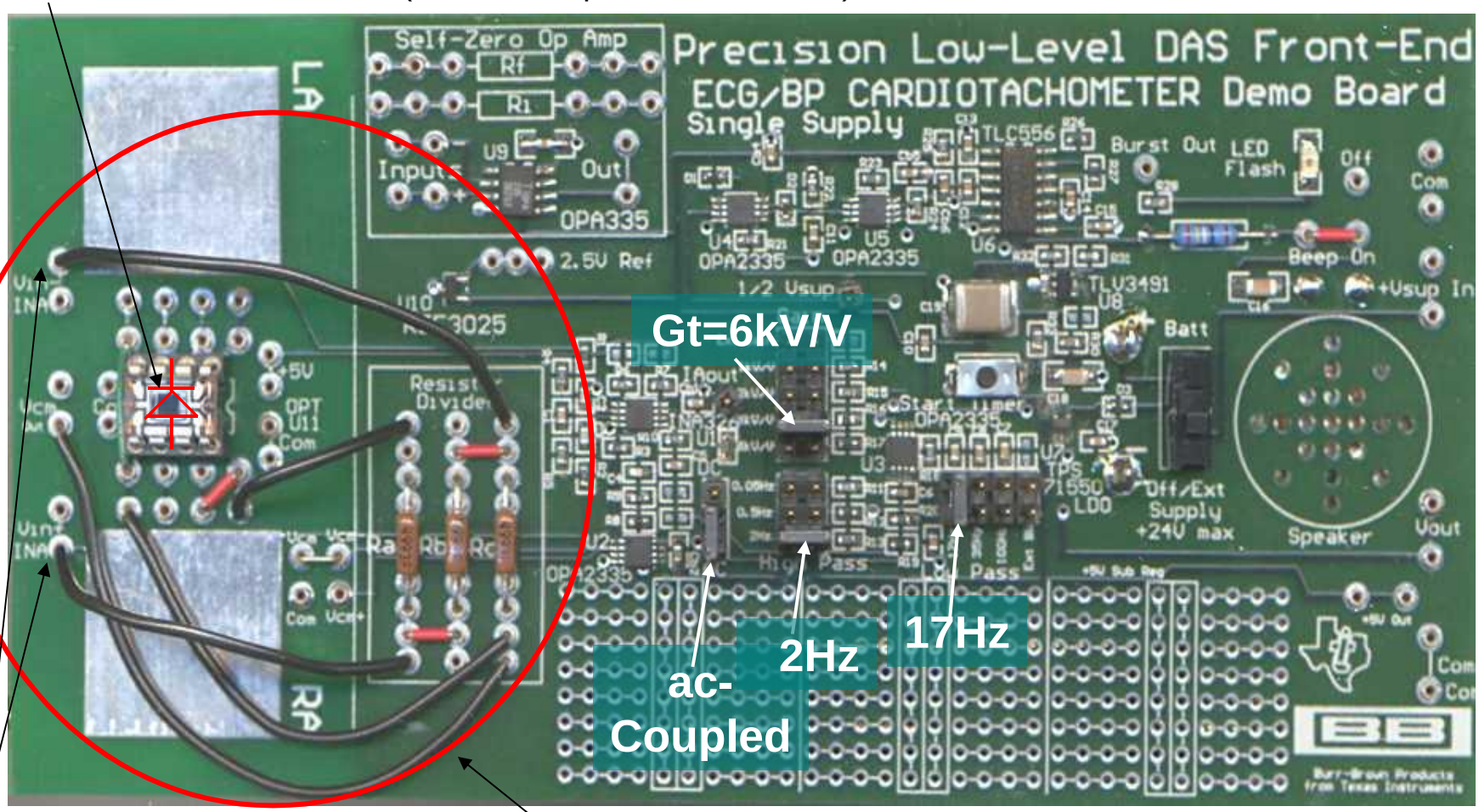


It's possible to omit A1, depending on resistances.

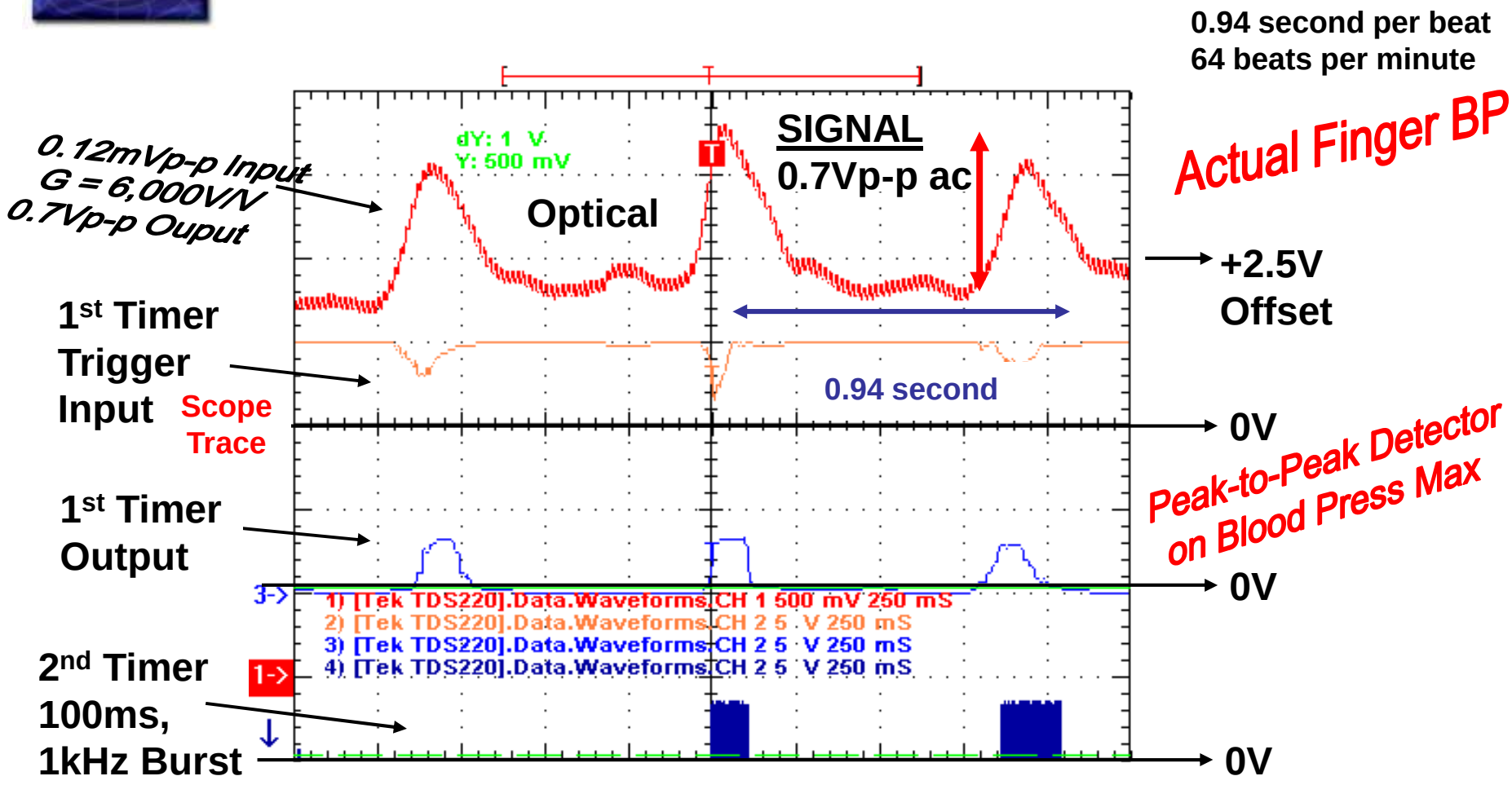
A Precision Low-Level DAS/ECG Cardiotachometer Demo Board - Optical Relative Blood Pressure Monitor

ac-Coupled

Photodiode Inside OPT101 (Can Use Separate Photodiode)



A Precision Low-Level DAS/ECG Cardiotachometer Demo Board - Optical Relative Blood Pressure Monitor



Missing Sound Burst
Did Not Trigger P-P Detector or Maybe
DIGITAL O-SCOPE Abnormality

A Precision Low-Level DAS/ECG Cardiotachometer Demo Board

The low-level DAS/ECG demo board:

- Provides a useful platform for low signal level circuit development.
- Is useful as a portable, self-contained cardiotachometer.
- Demonstrates the ability of very small amplitude signals to be amplified in the presence of large common-mode signals.
- Provides either AC or DC coupling, but very large gain may be difficult to use for DC due to offset.
- Accommodates a variety of medical and non-medical sensors and applications.