



A Precision Low-Level DAS/ECG Cardiotachometer Demo Board

Created by Dr. John Brown

Prepared by Thomas Kuehl & Laura Groskie

Texas Instruments – Tucson, AZ



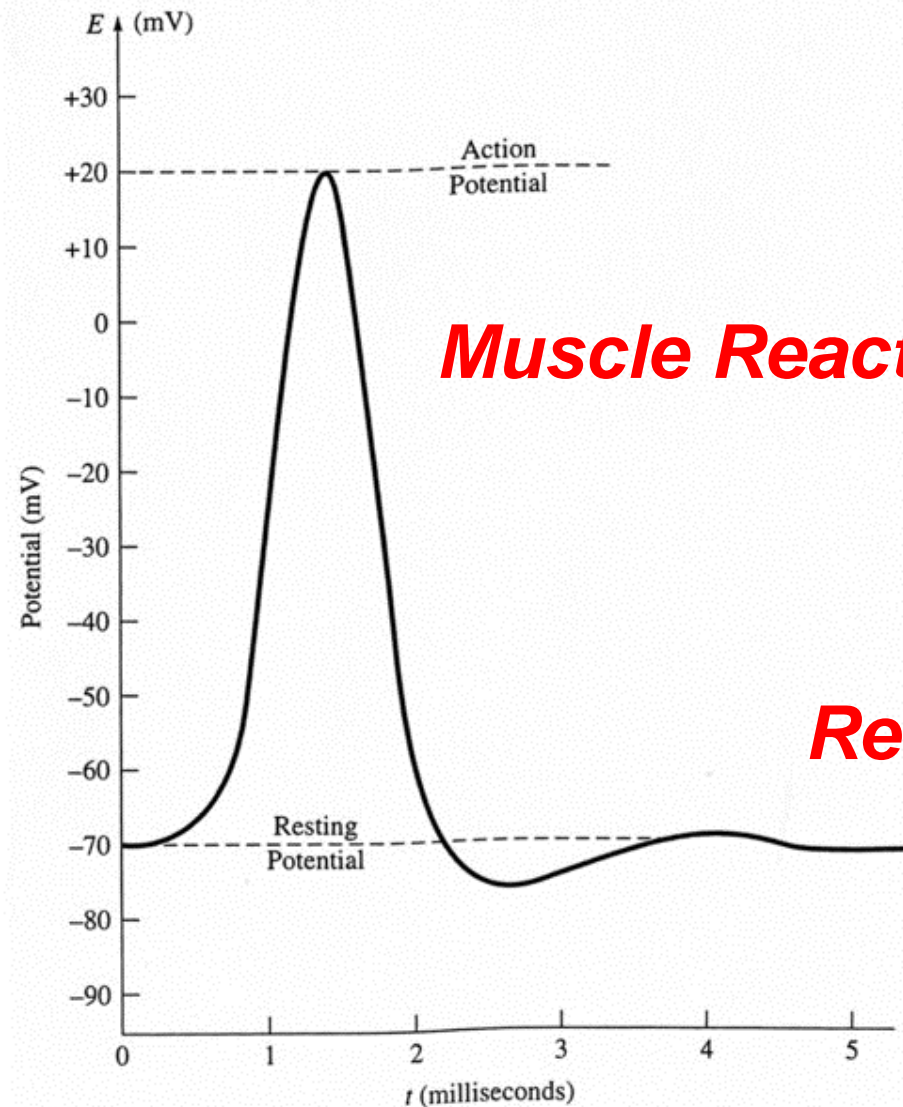
A Precision Low-Level DAS/ECG Cardiotachometer Demo Board

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

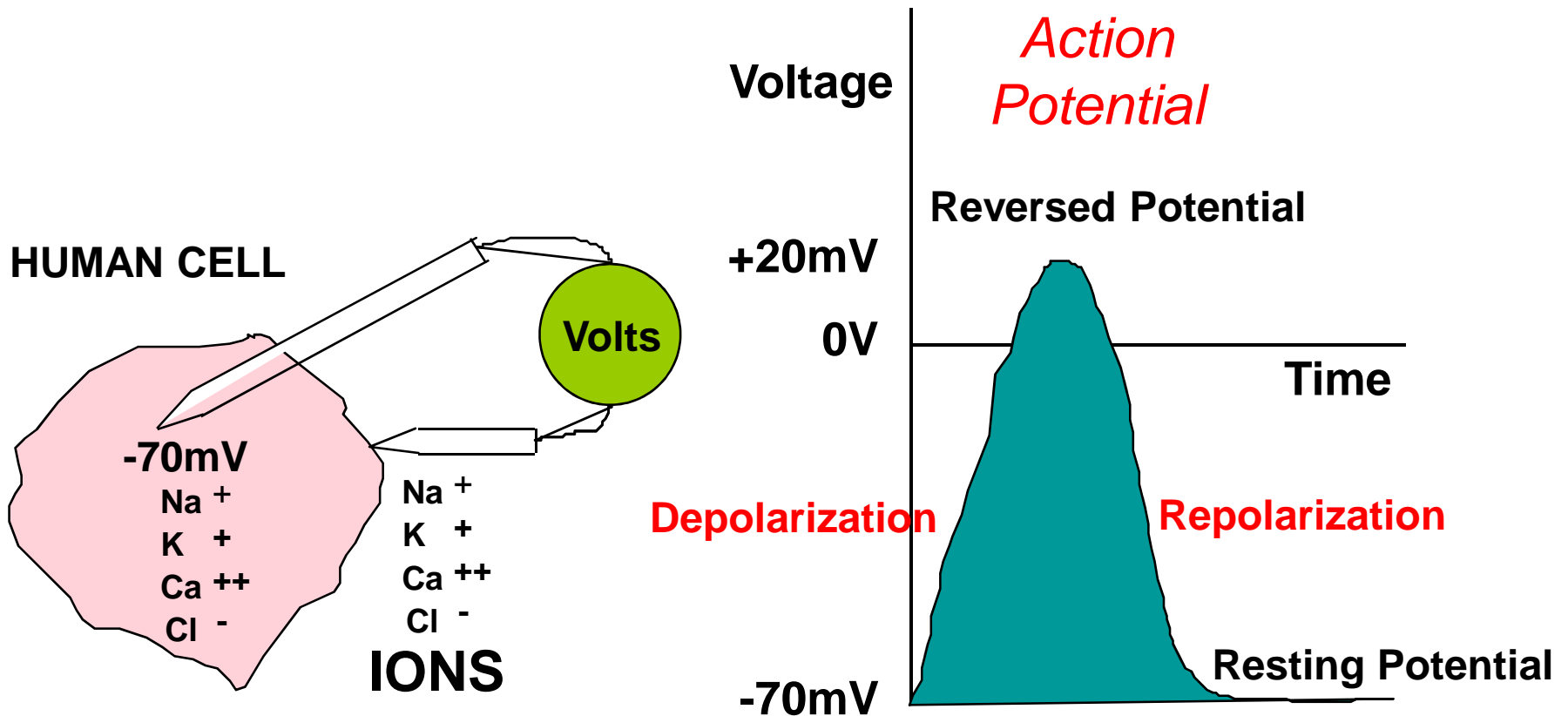
Resting State



Biopotentials from Cells

Electrical Signals From the Body

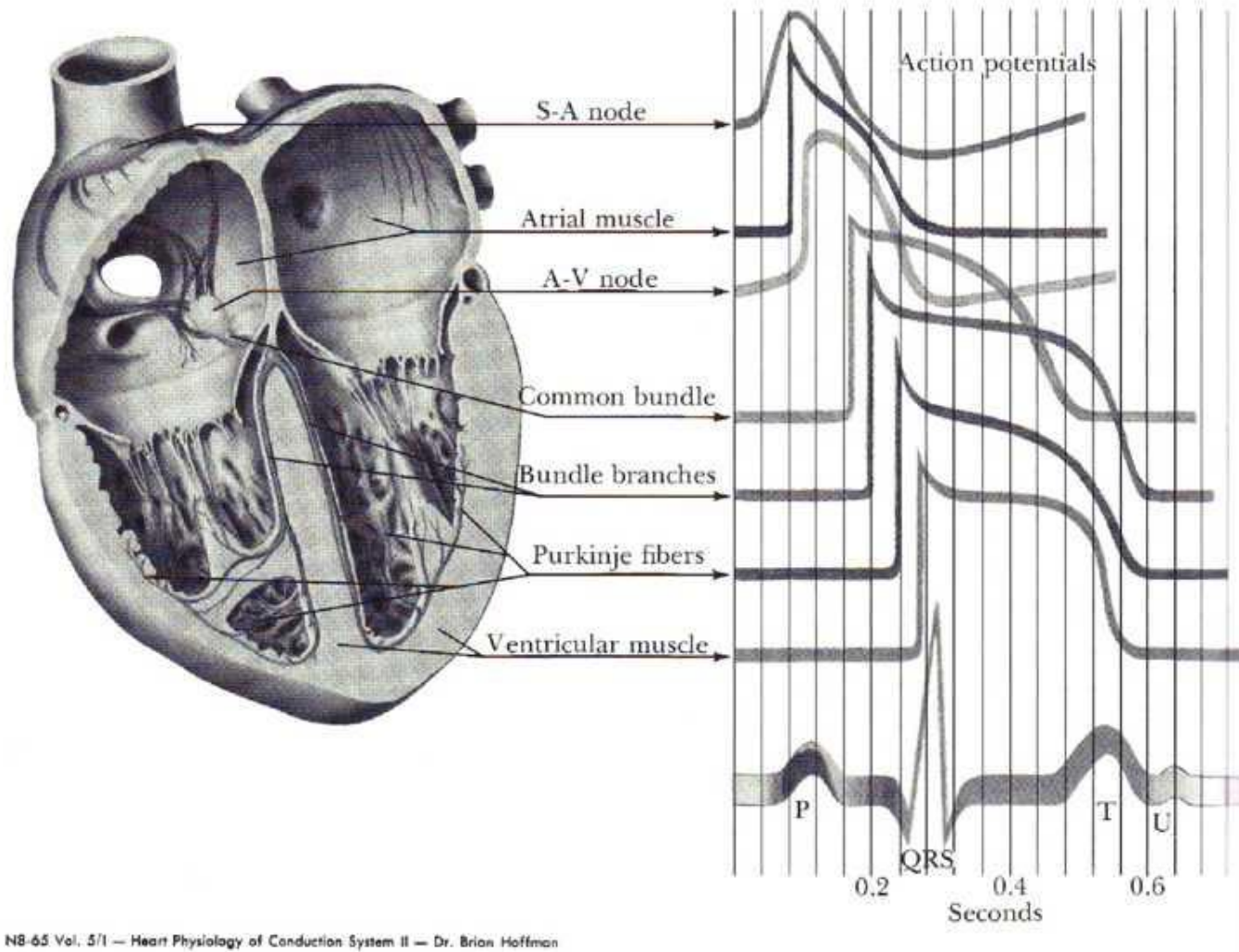
EVERY CELL IS LIKE A LITTLE BATTERY





Biopotentials from Cells

Electrical Signals From the Heart

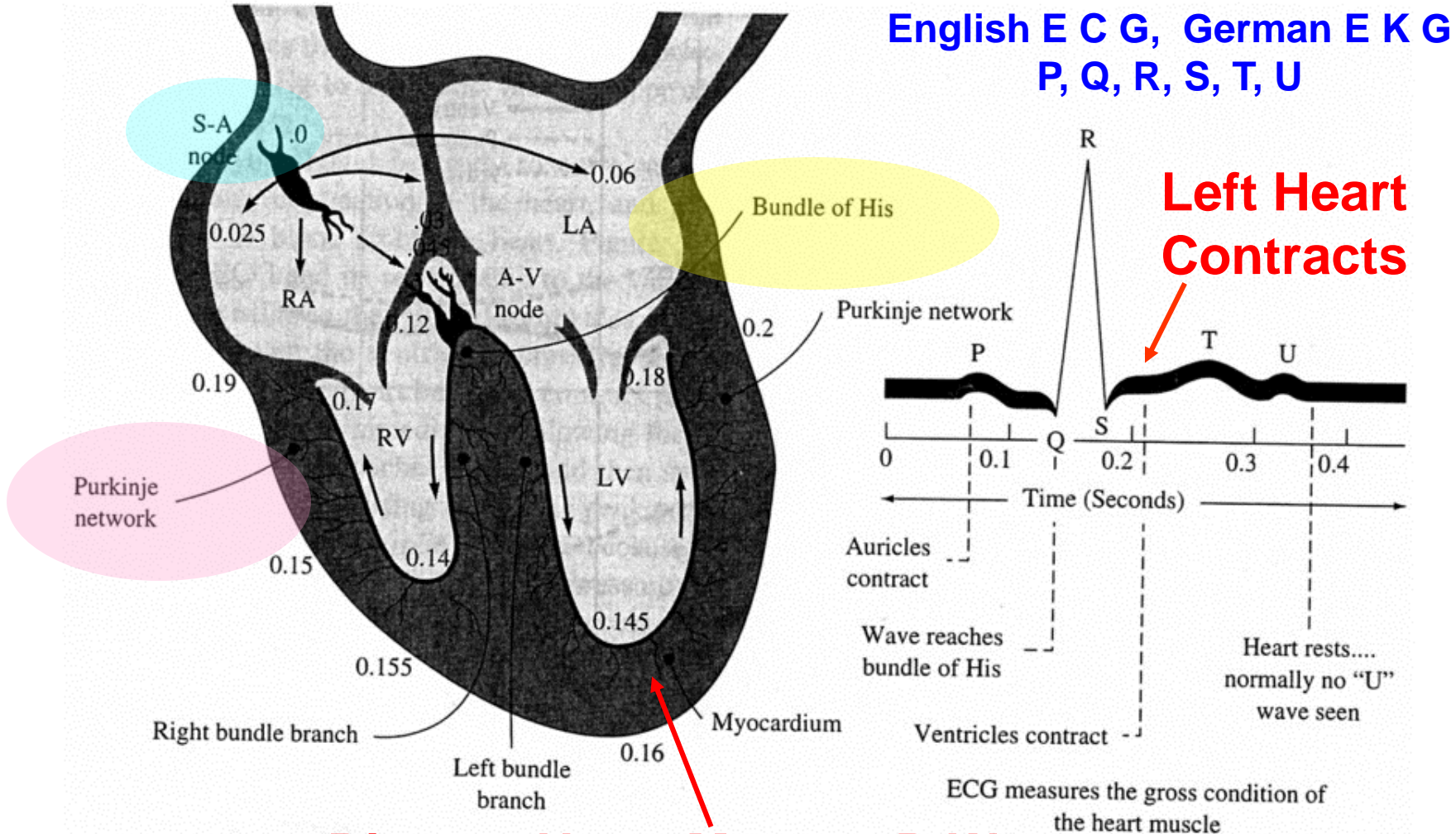


N8-65 Vol. 5/1 — Heart Physiology of Conduction System II — Dr. Brian Hoffman



Cardiac Conduction System of the Heart

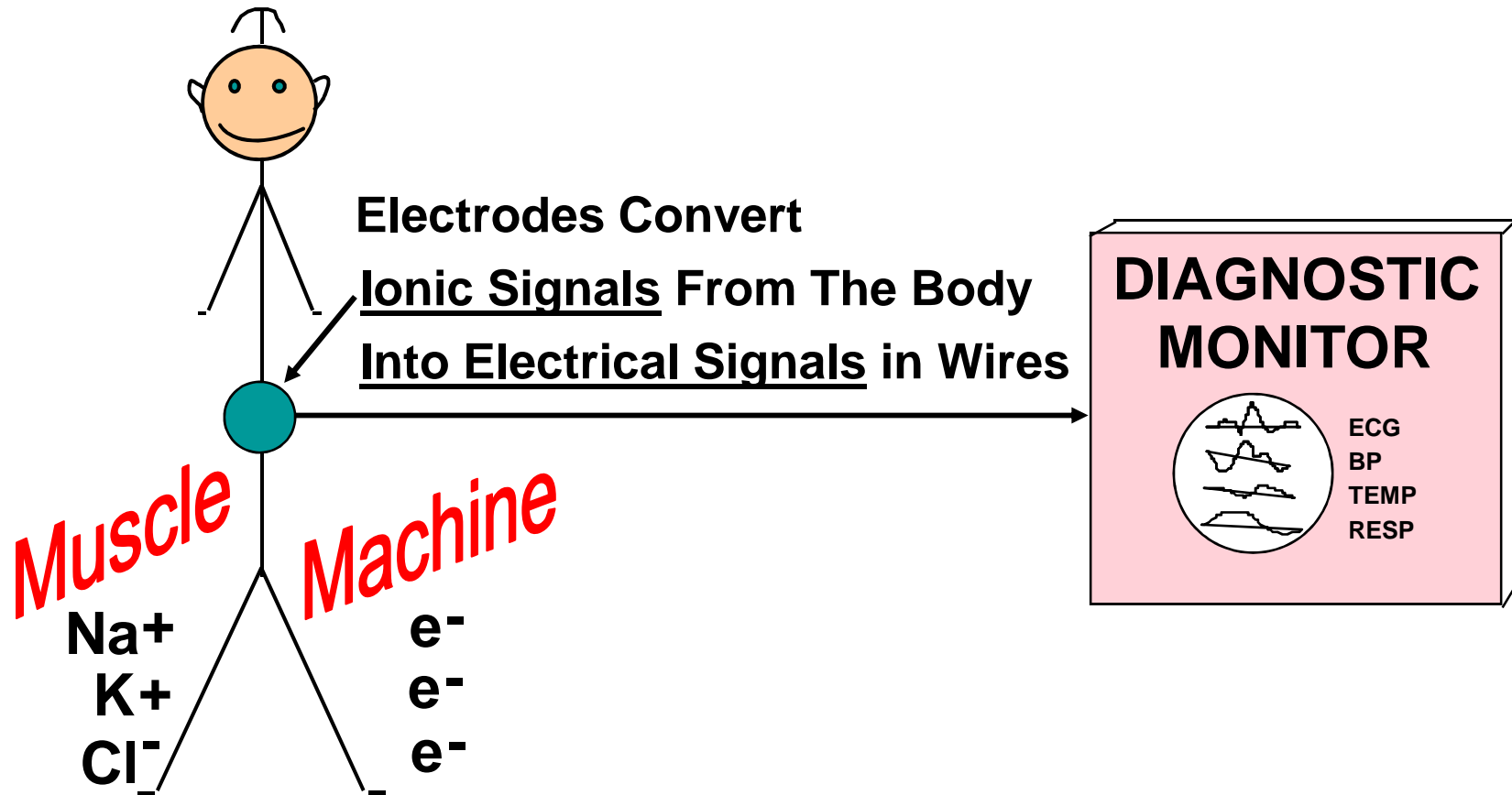
ECG Waveforms





Biopotentials from Cells - Electrodes

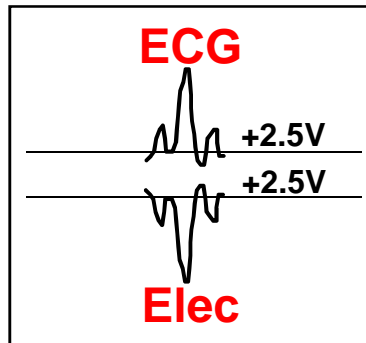
IONS to ELECTRONS CONVERTER



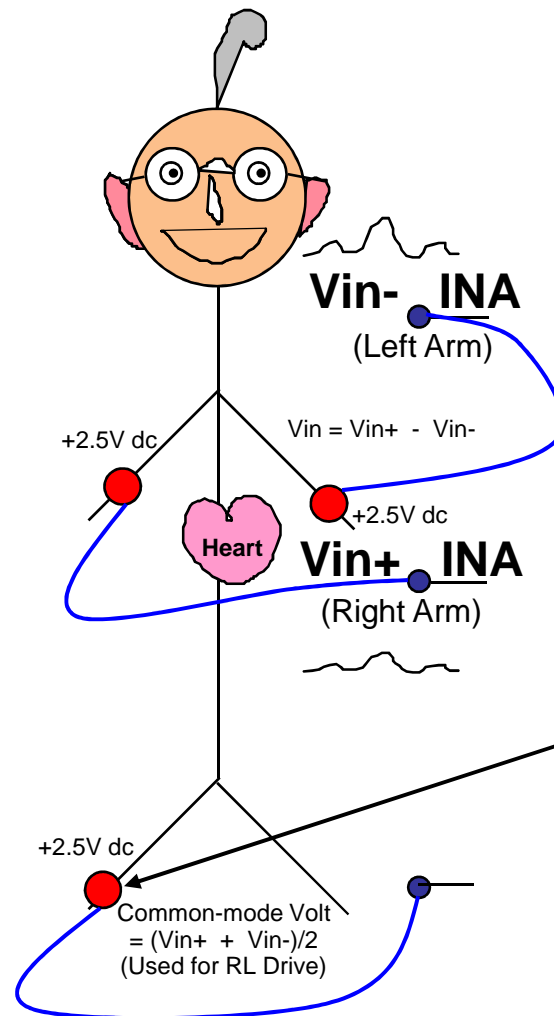


Basic ECG electrode connections

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

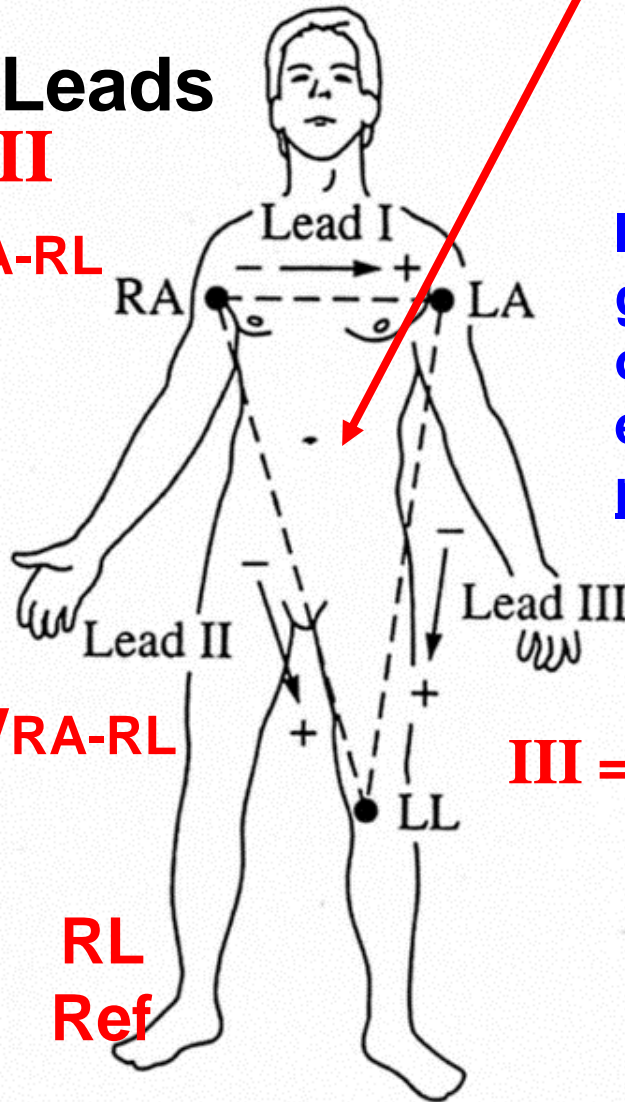
3 Derived Leads
I, II, III

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

3 Body Electrodes

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

RL
Ref



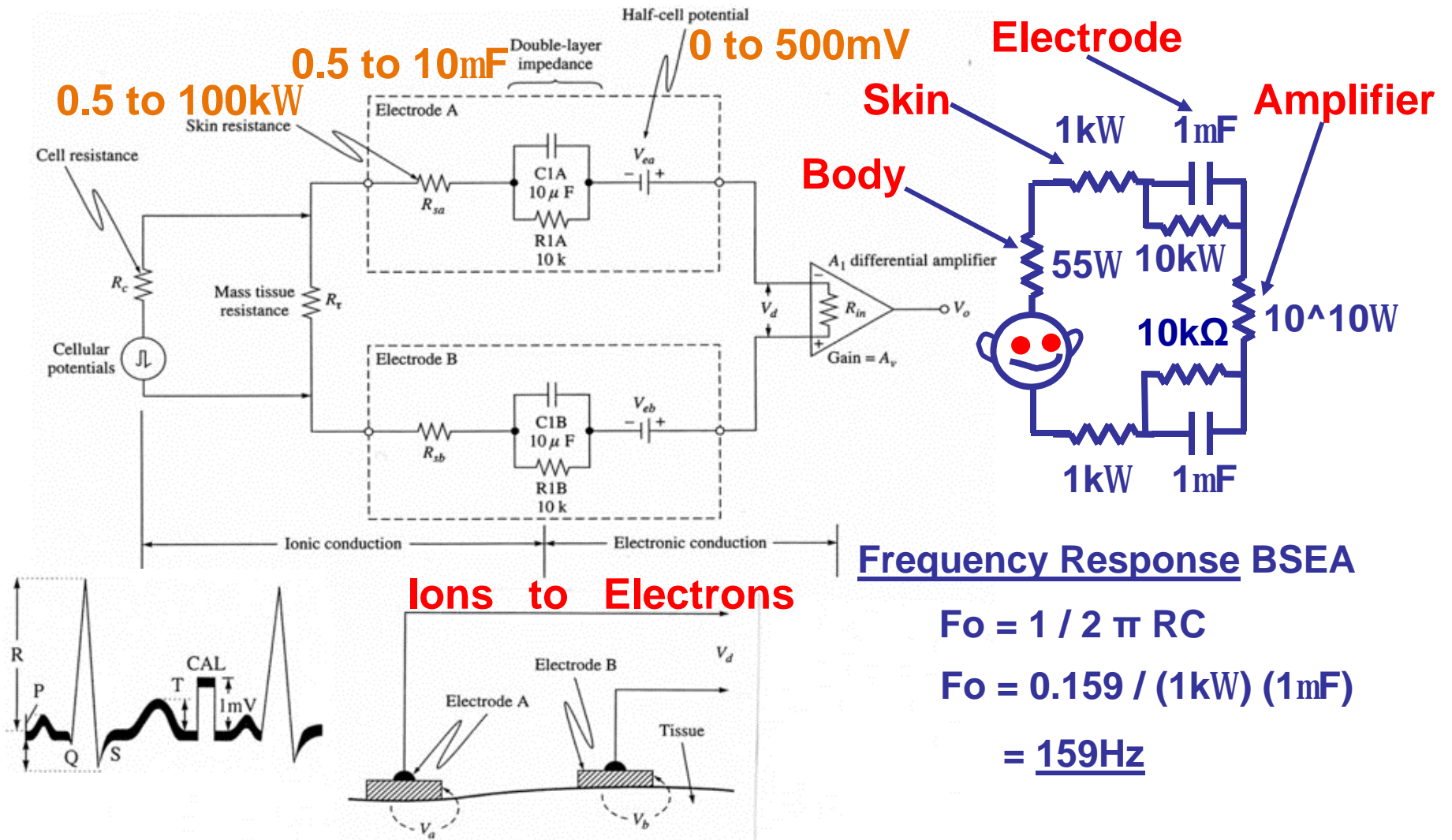
Einthoven's Law

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.

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

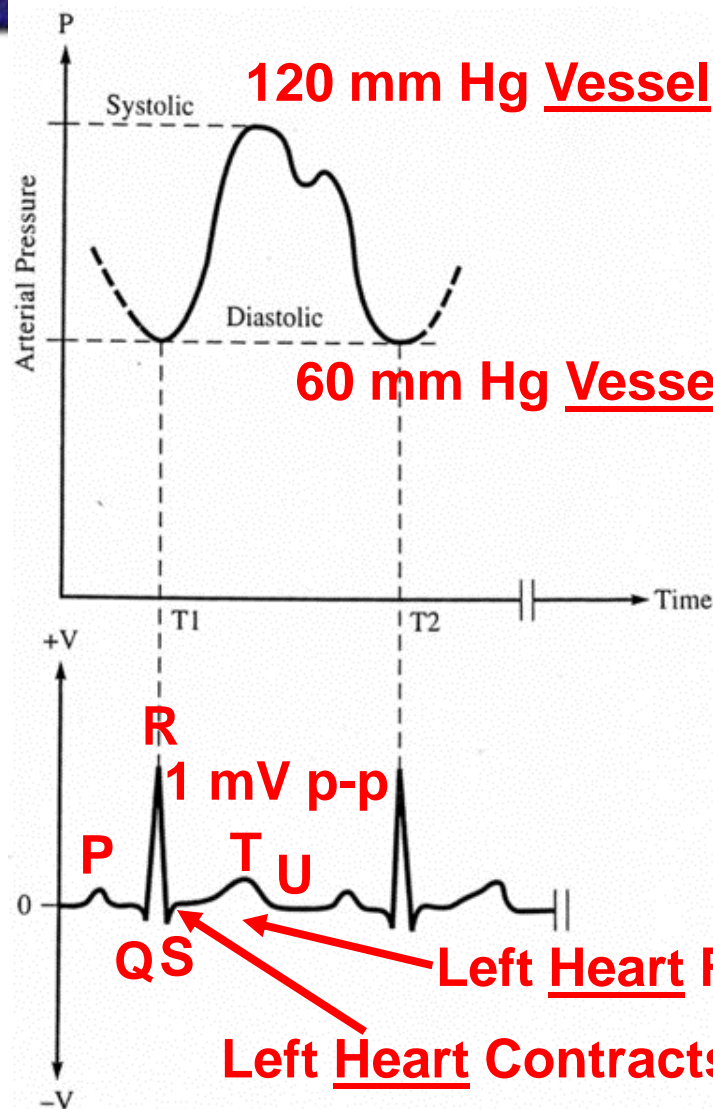


ECG Electrode – Electrical Model





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

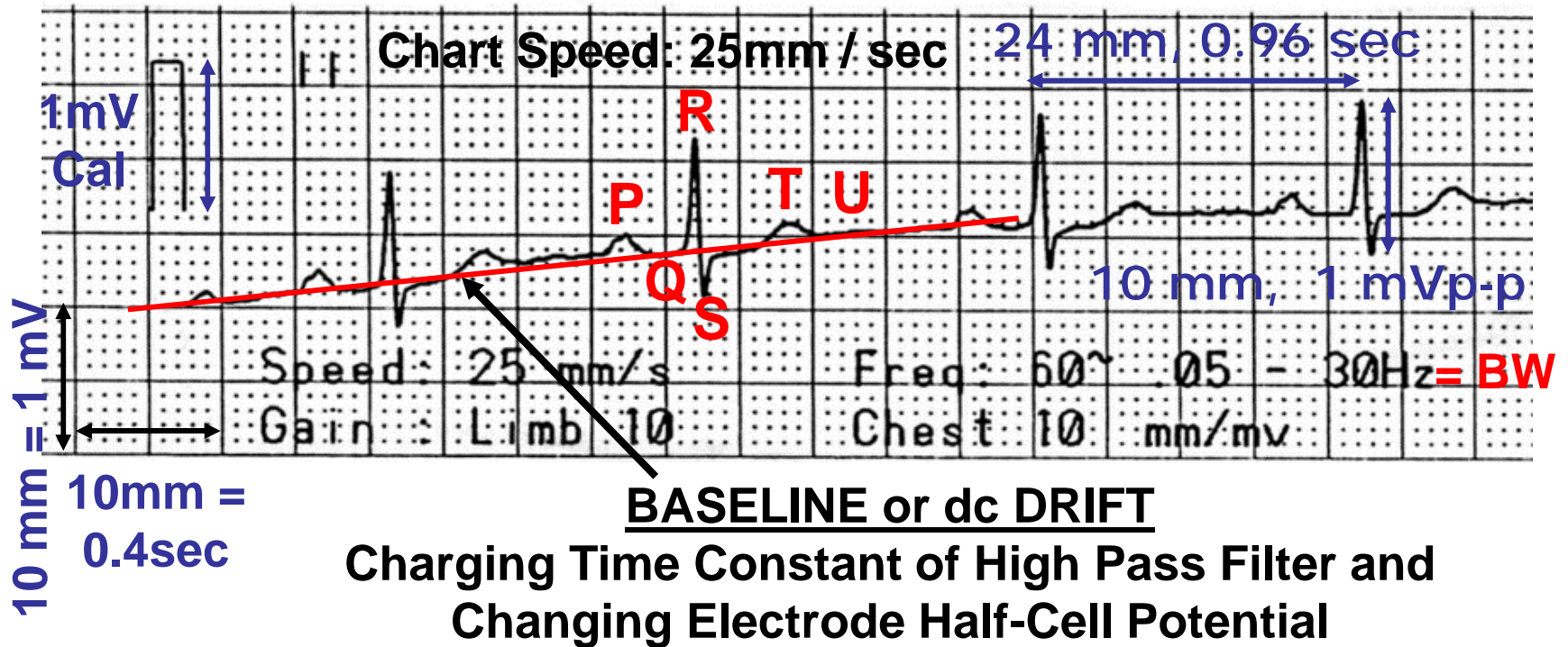
100Hz BW, 70 harmonics

Left Heart Relaxes

Left Heart Contracts



Actual ECG - Normal



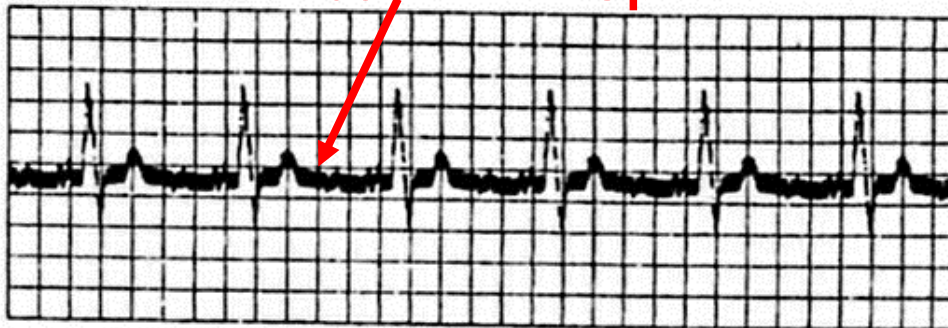
$$24 \text{ mm} \times 1 \text{ sec} / 25 \text{ mm} = 0.96 \text{ sec} / \text{beat} \Rightarrow 1 / 0.96 \text{ sec} = 1.04 \text{ bps}$$

62 bpm
at rest



ECG Irregular Tracings Due to Artifacts

60Hz Pick-Up



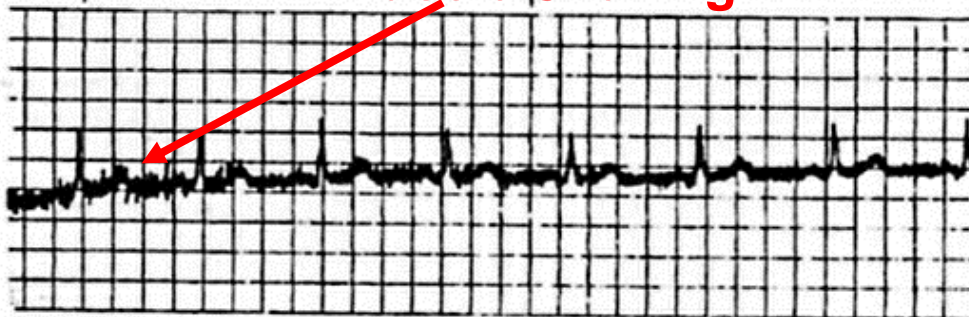
ALTERNATING CURRENT (AC) INTERFERENCE

Baseline dc Instability



IRREGULAR BASELINE

Muscle Shaking



SOMATIC TREMOR

Baseline or dc Drift

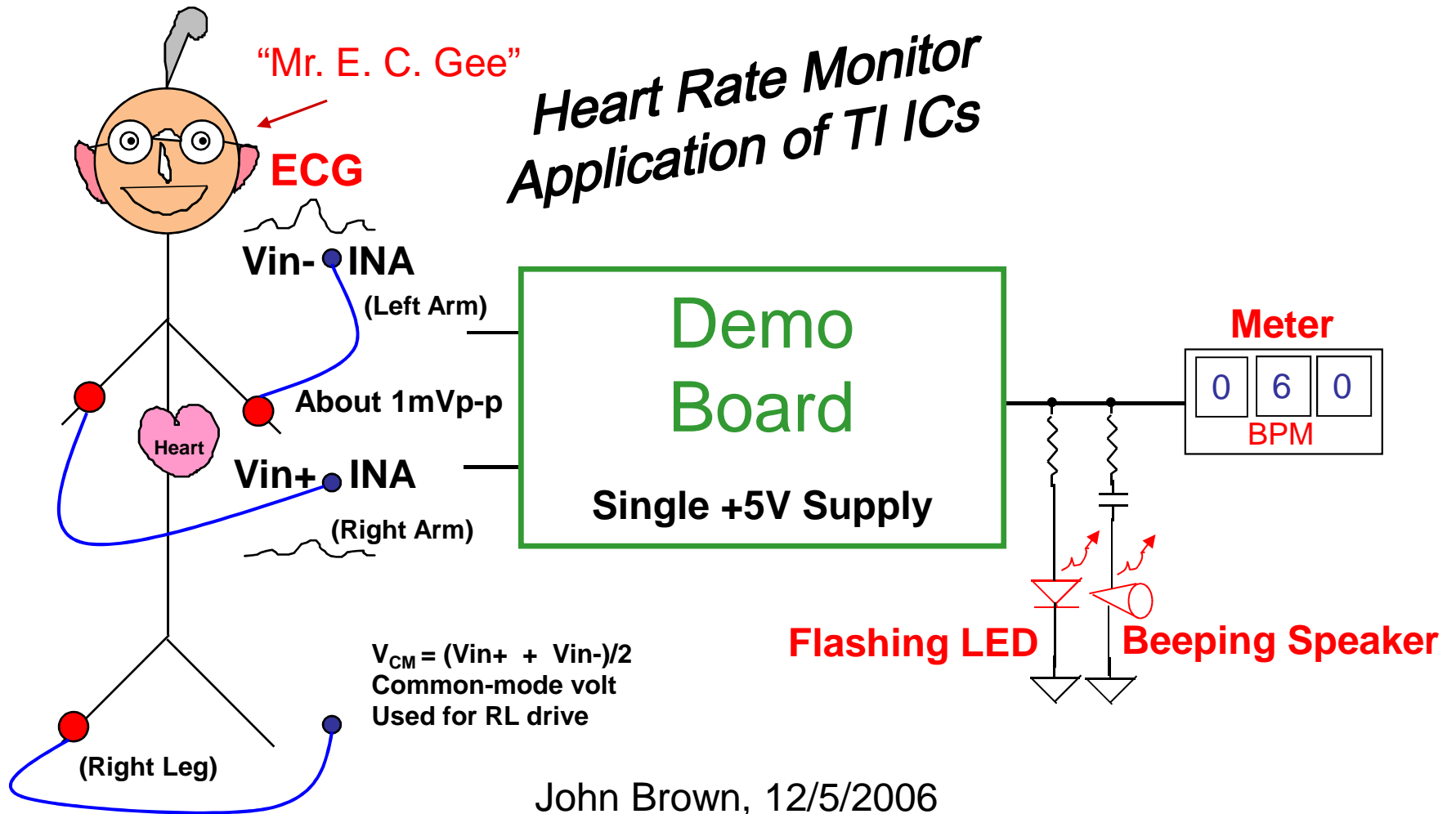


WANDERING BASELINE



A Precision Low-Level DAS/ECG Cardiotachometer Demo Board

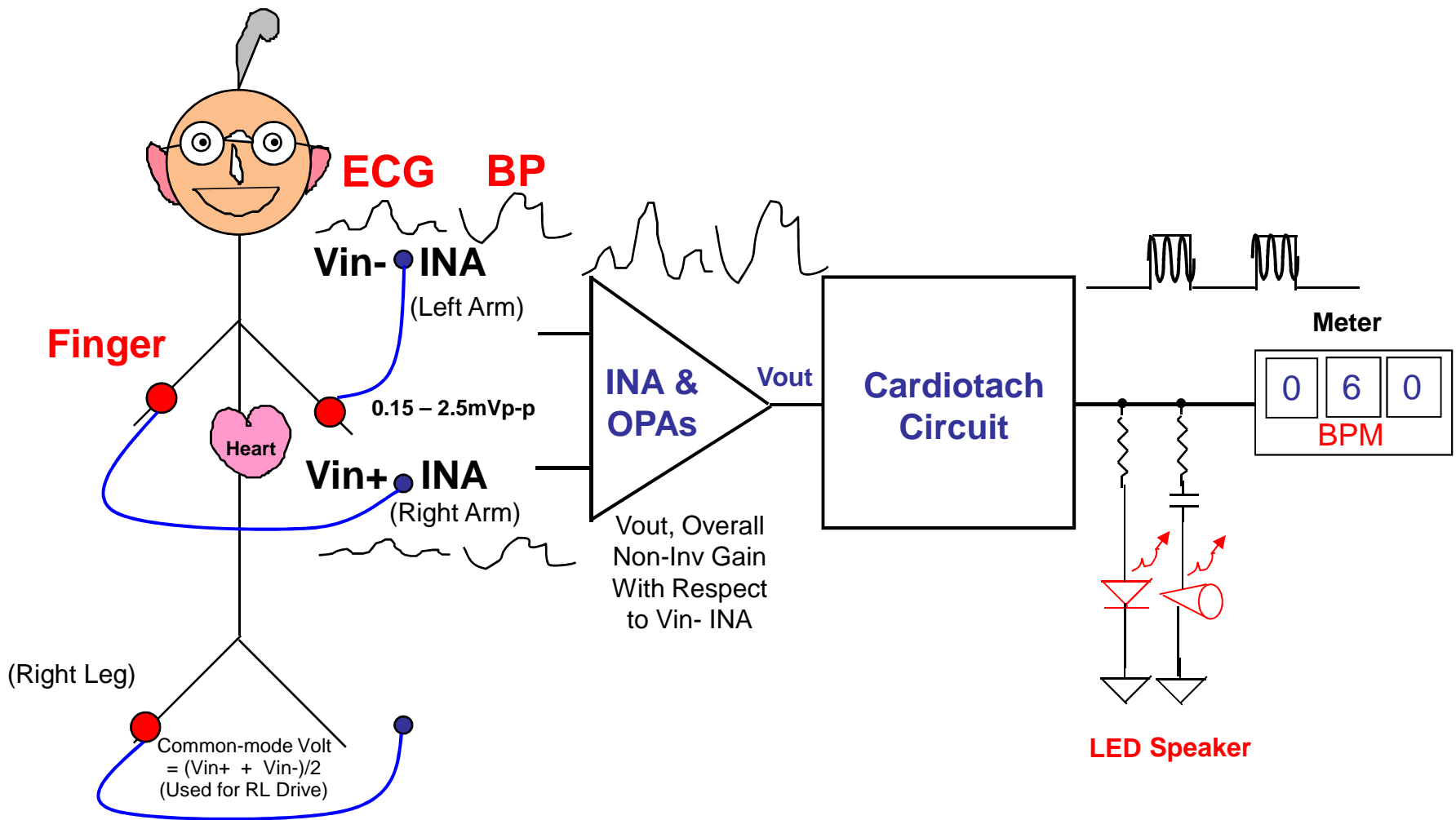
Can Also Be Used As Precision Low-Level Data Acquisition System Front-End



John Brown, 12/5/2006



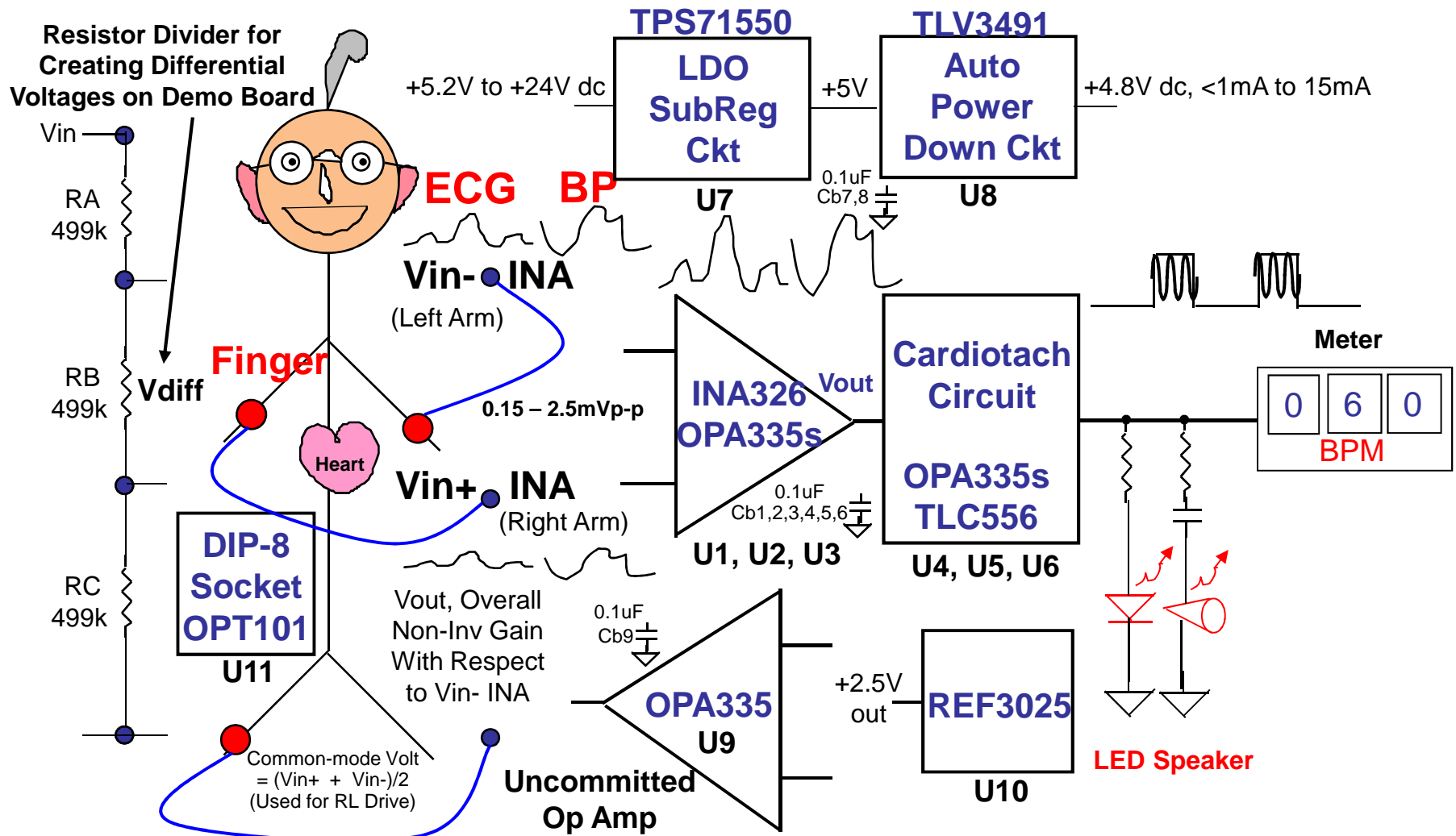
A Precision Low-Level DAS/ECG Cardiotachometer Demo Board





A Precision Low-Level DAS/ECG Cardiotachometer Demo Board

Uses 7 TI IC Types, 11 U's Total



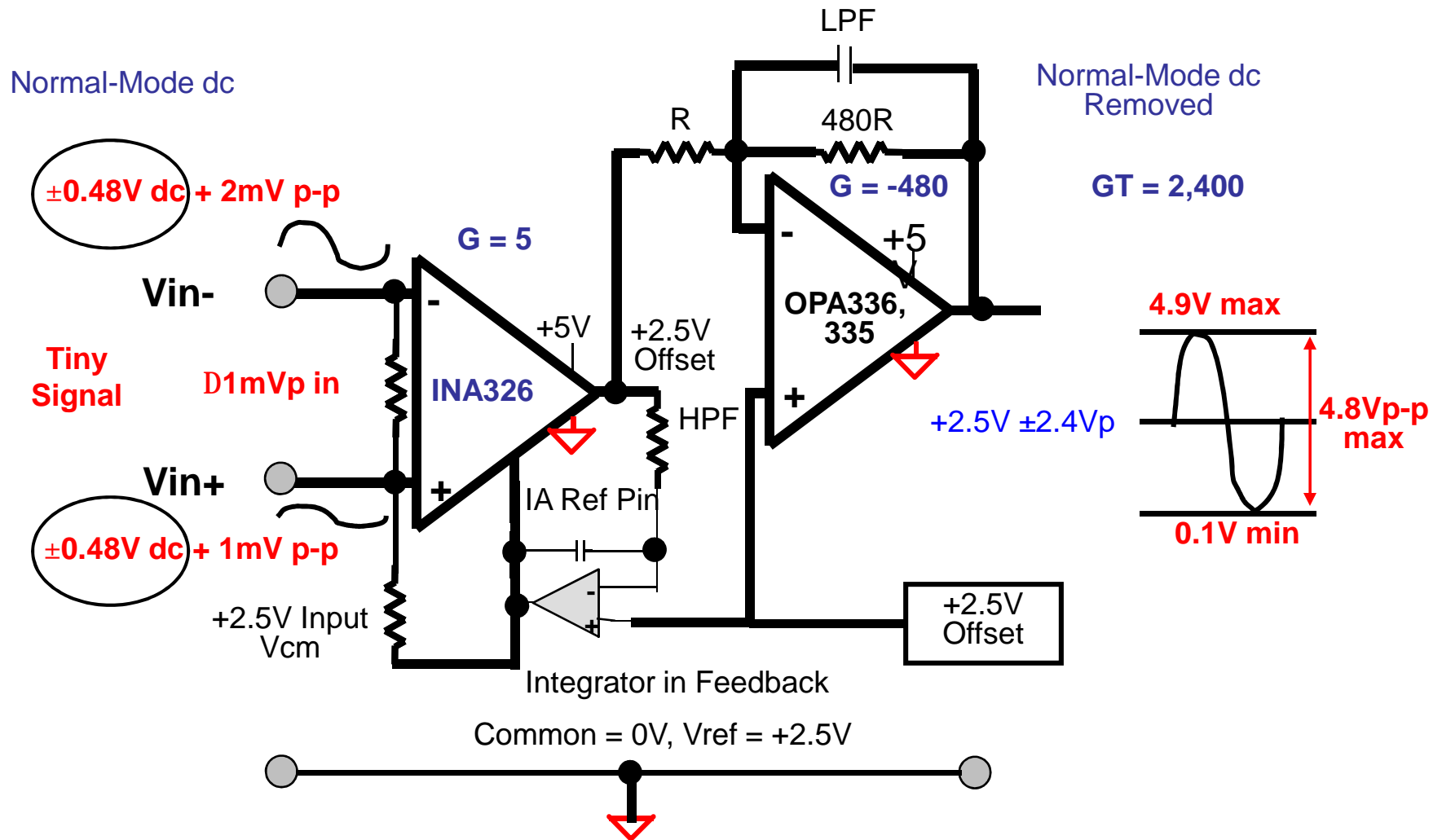
Technology for Innovators™

TEXAS INSTRUMENTS



A Precision Low-Level DAS/ECG Cardiotachometer Demo Board

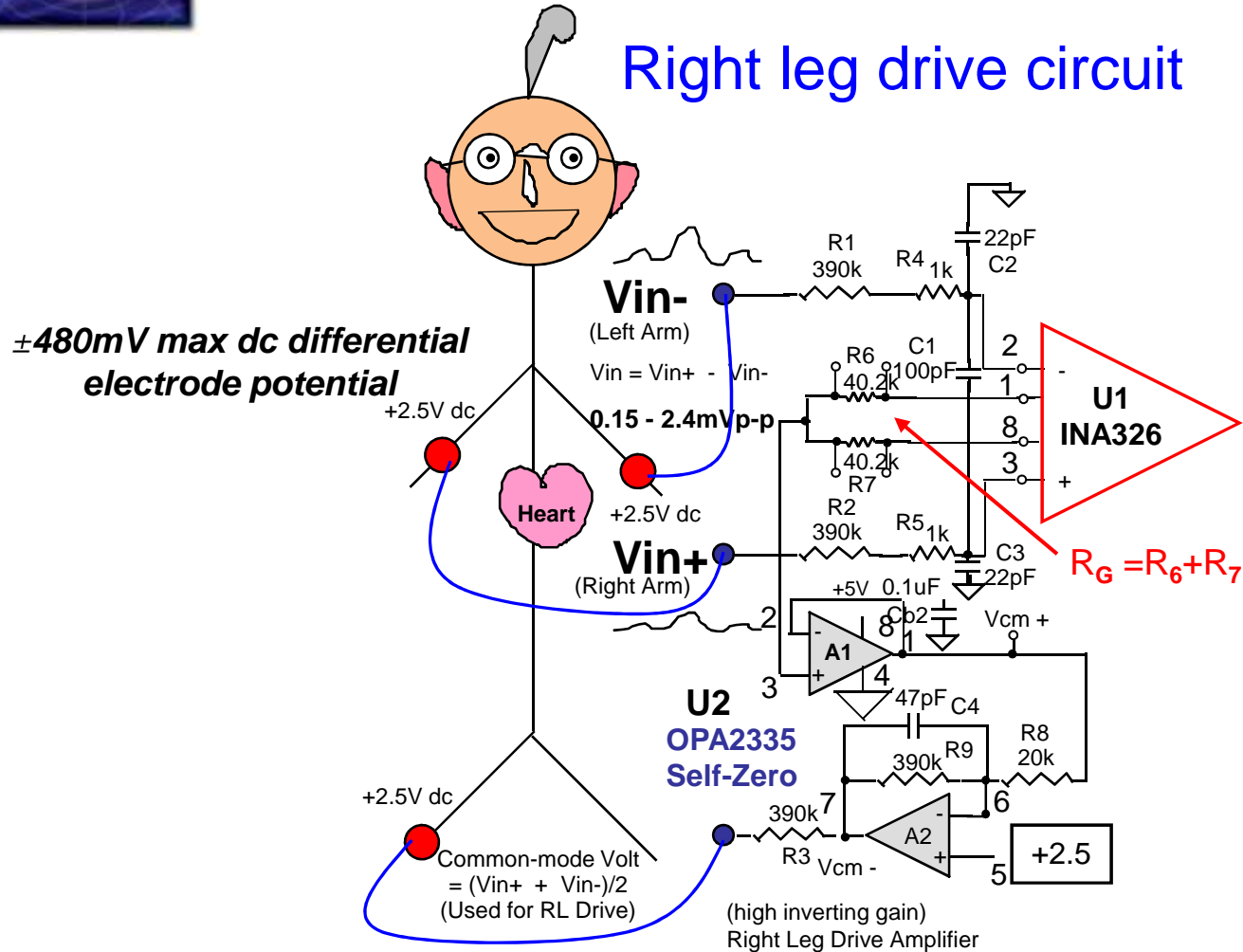
AC-coupled input stage





A Precision Low-Level DAS/ECG Cardiotachometer Demo Board

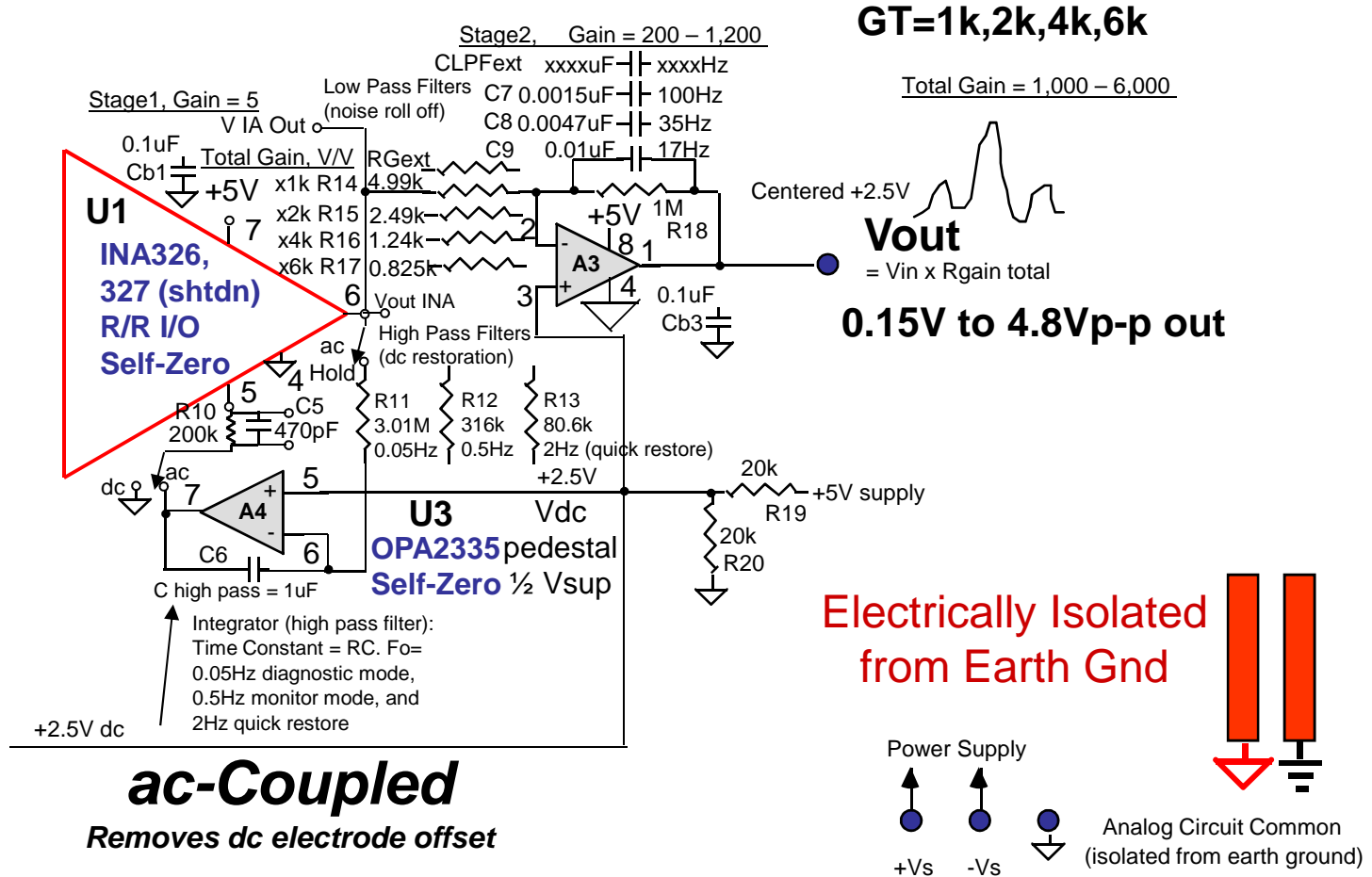
Right leg drive circuit





A Precision Low-Level DAS/ECG Cardiotachometer Demo Board

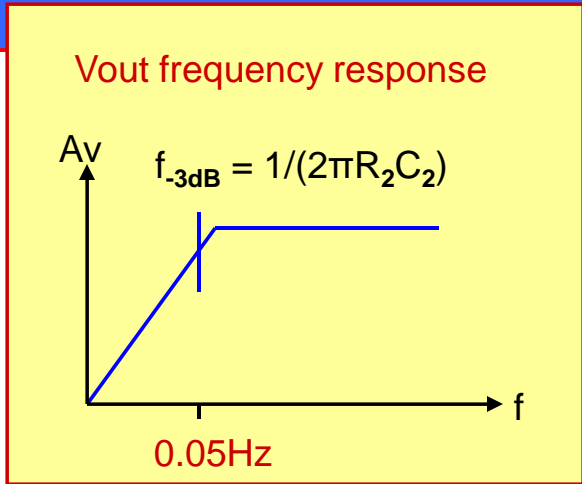
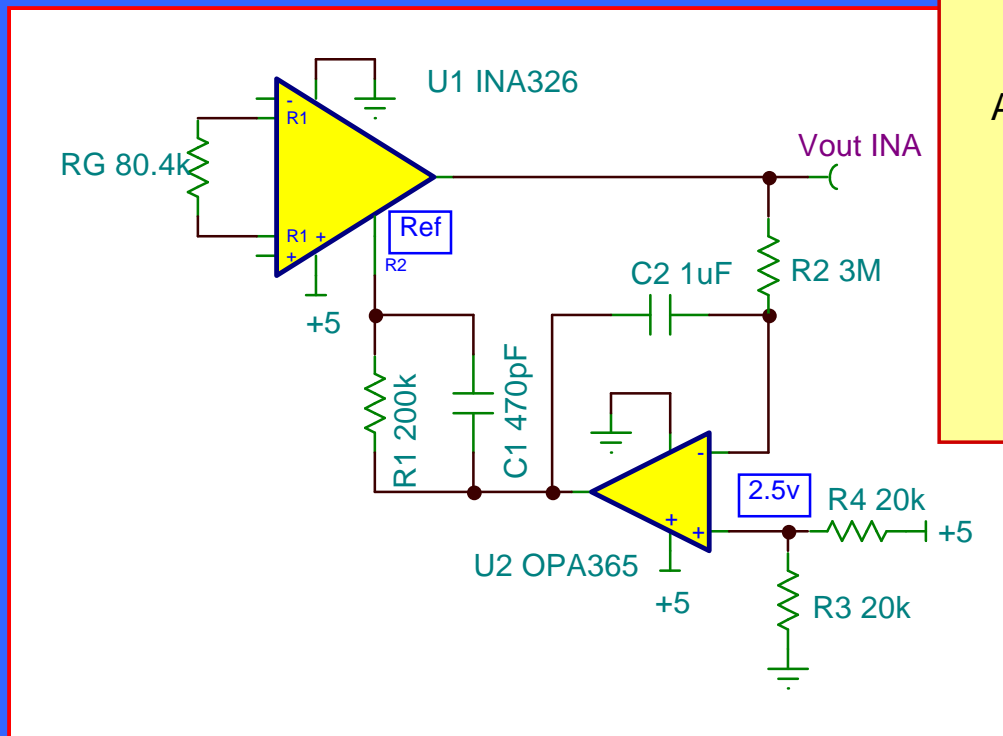
CMOS +5V SINGLE SUPPLY, INA326/7 & OPA2335





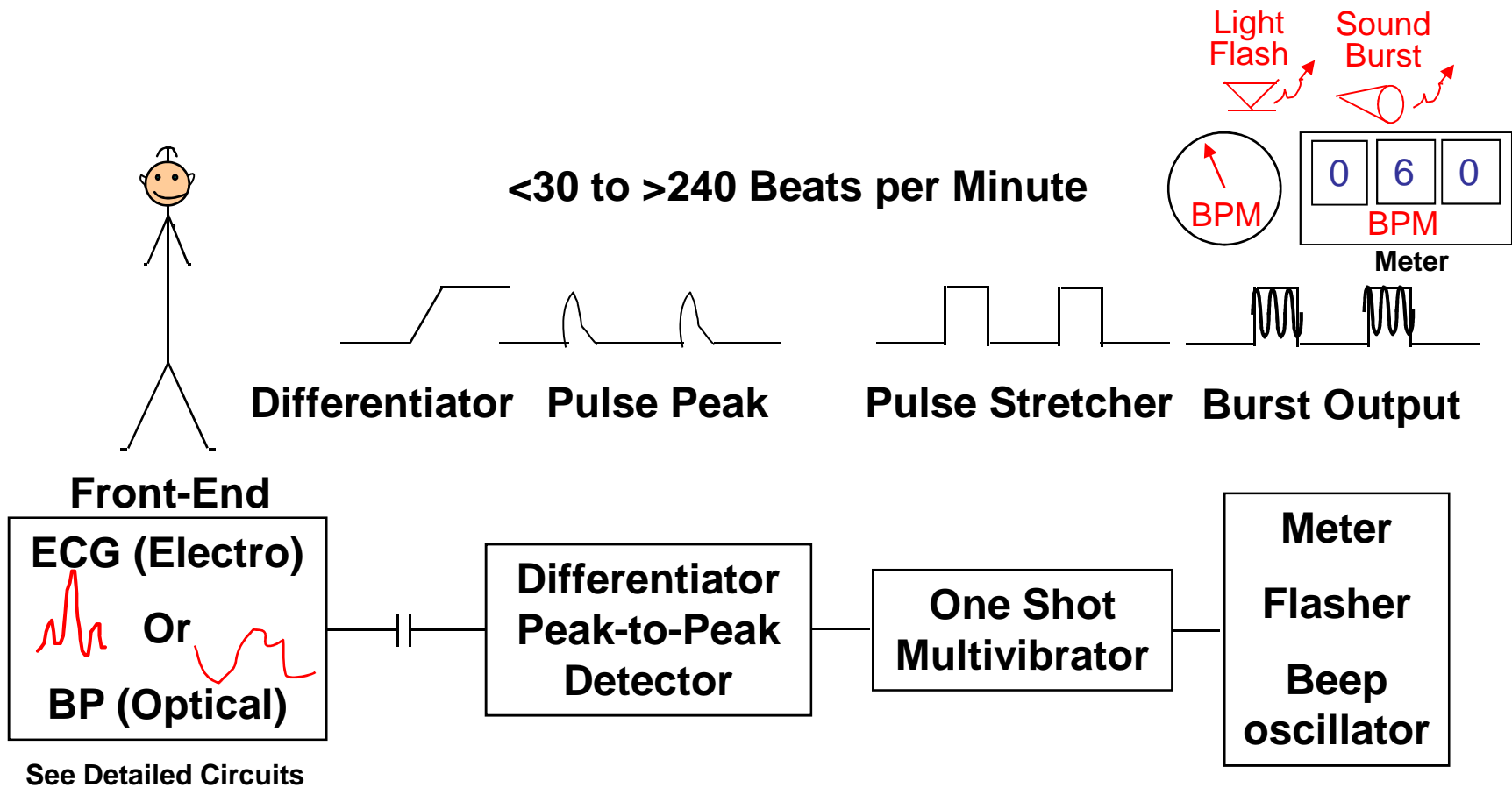
A Precision Low-Level DAS/ECG Cardiotachometer Demo Board

DC restorer - removes electrode offset





A Precision Low-Level DAS/ECG Cardiotachometer Demo Board

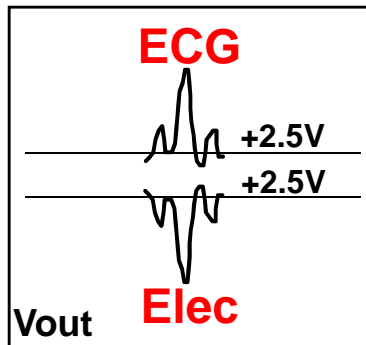




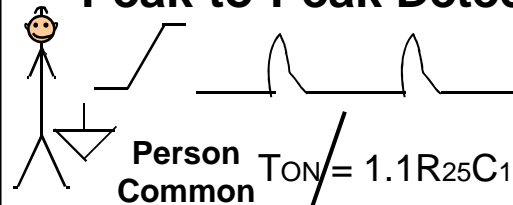
A Precision Low-Level DAS/ECG Cardiotachometer Demo Board

+5V Single Supply

Front-End



Differentiator & Pos-Neg Peak-to-Peak Detector One Shot



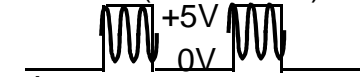
<30 to >240 Beats per Minute

Pulse Stretcher

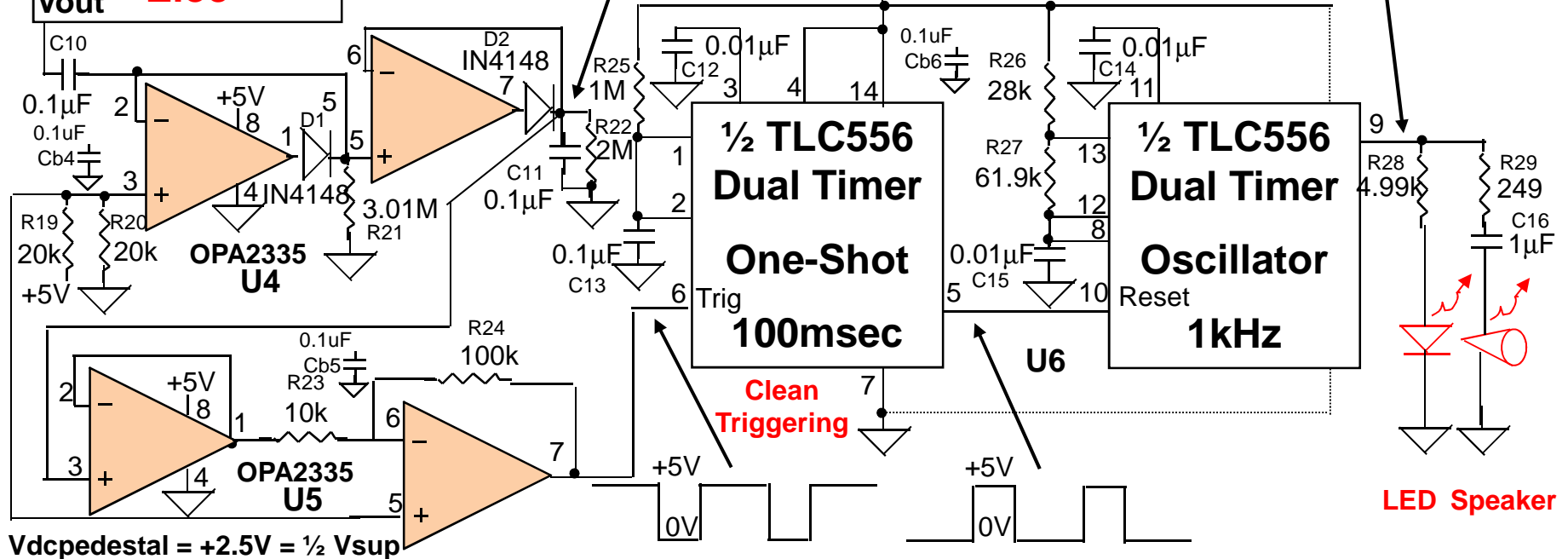
~50% osc duty cycle

Burst Output

$$f_{osc} = 1.44 / C_{15} (R_{26} + 2R_{27}) \approx 1kHz$$



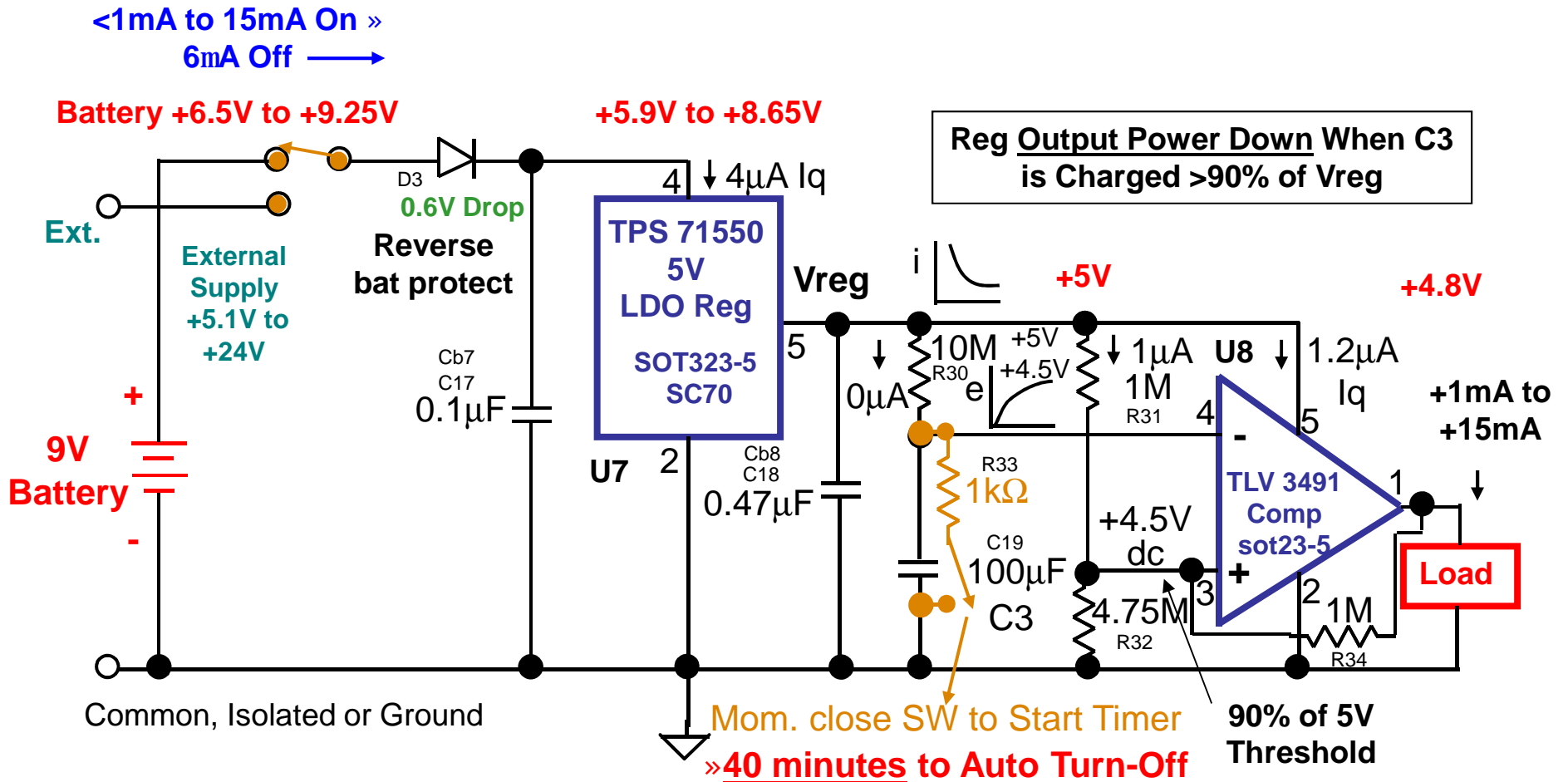
$$t_{hi} = 0.693 C_{15} (R_{26} + R_{27}), t_{lo} = 0.693 C_{15} R_{26}$$





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

Left Thumb (Red circle)

Right Thumb (Red circle)

Right Finger Underneath (Red circle)

OPT Not Used In This Example (Green box)

ac-coupled (Red text)

Forward, Out put Swing Up From Mid +2.5Vdc Towards +5V (White text)

ECG Waveform Appear at Vout (Black text)

Gain $G = 1\text{ kV/V}$ (Green box)

0.05Hz to 35Hz BW (Green box)

Plugged Into ac-Coupled Position (White text)

Speaker On (Orange arrow)

Off (Orange arrow)

Flash (Orange arrow)

Com (Orange arrow)

U10 REF3025

Resistor Divider

Self-Zero Op Amp

Inputs

Out

OPA335

OPA2335

U4

U5

U6

U7

U8

U9

U11

U12

U13

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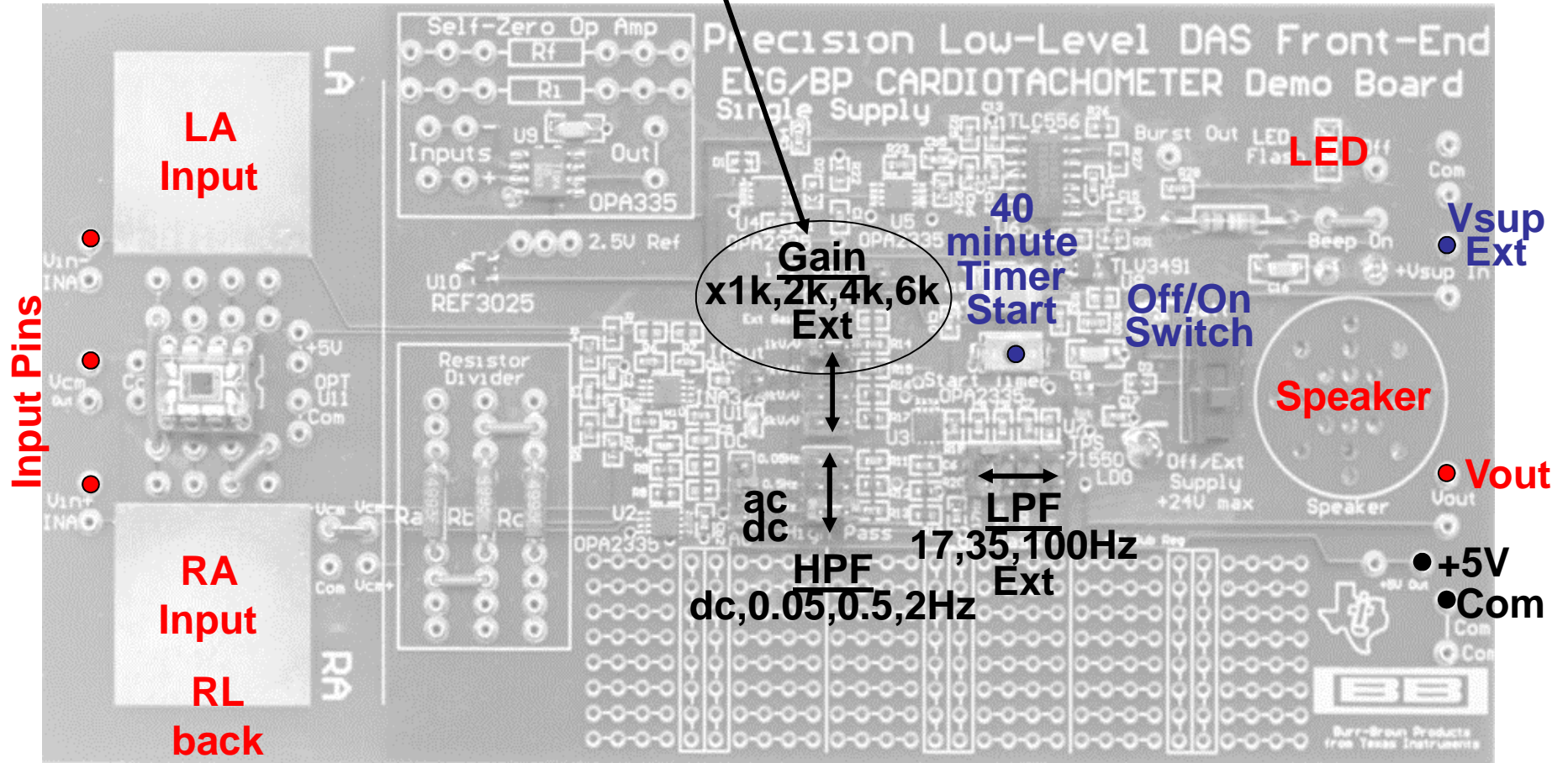
U921

U922



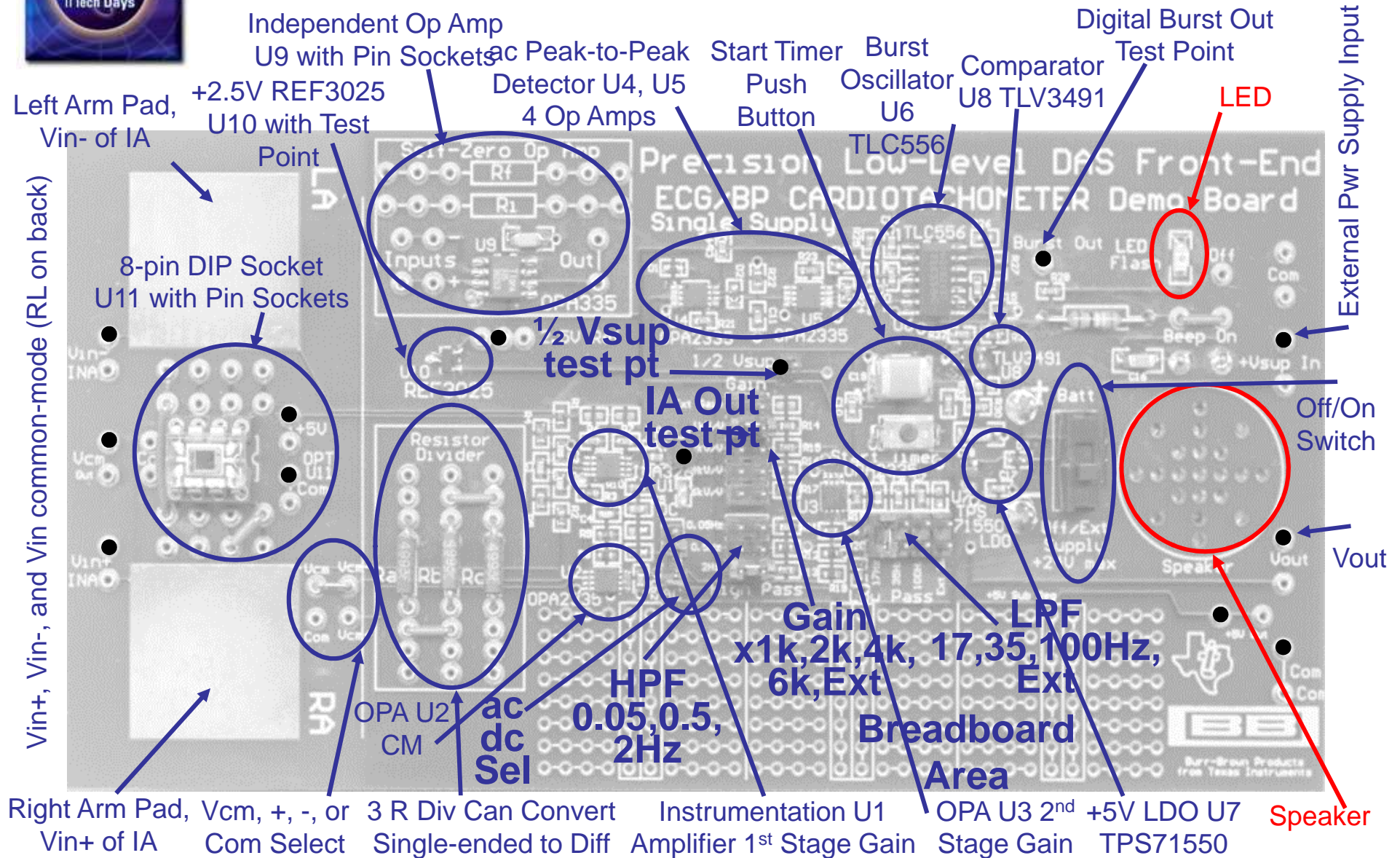
A Precision Low-Level DAS/ECG Cardiotachometer Demo Board – top side

Gain Control, Selected By Changing Shorting Bar Position





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

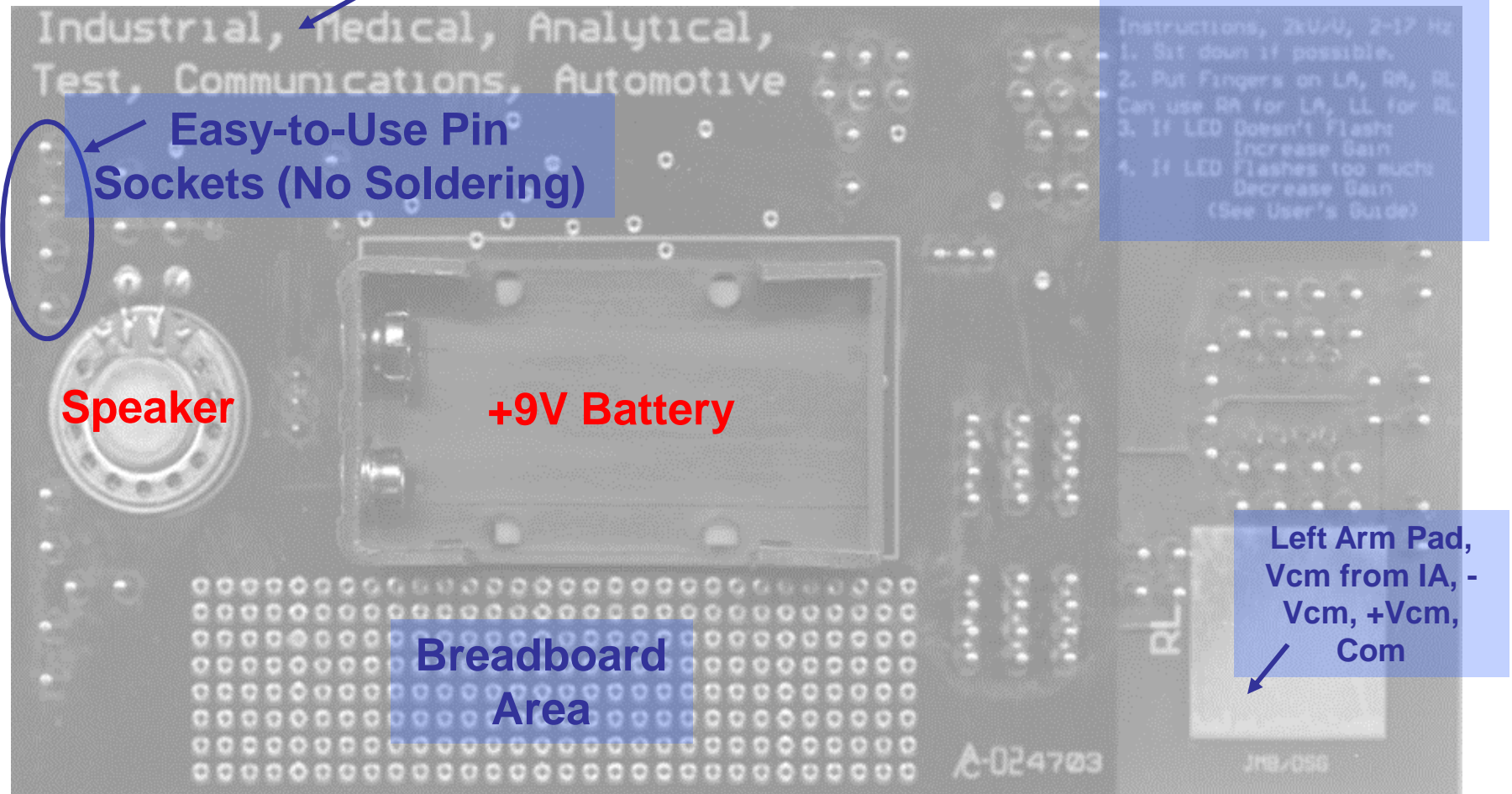




A Precision Low-Level DAS/ECG Cardiotachometer Demo Board – back side

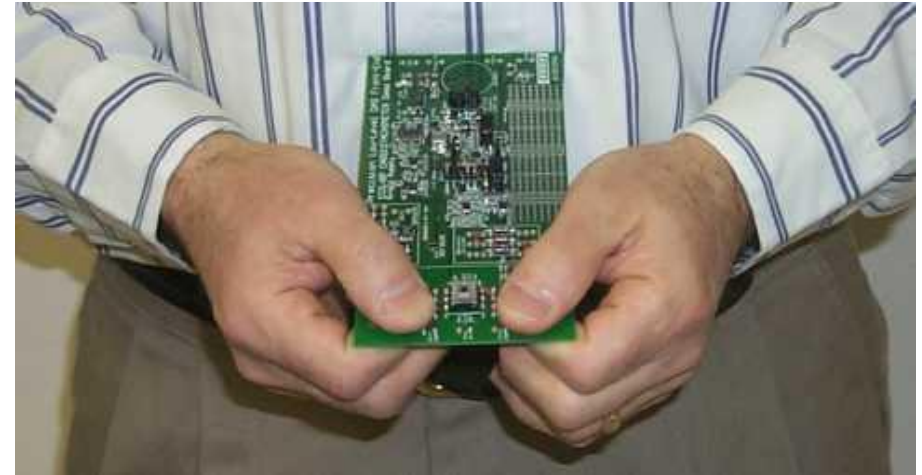
This Demo Board Supports Many Applications

Brief Instructions





Low-Level DAS / ECG Cardi tachometer Demo Board - Standing



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





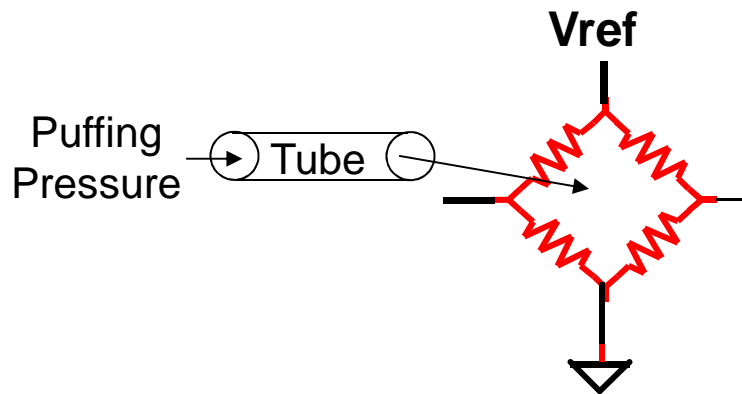
A Precision Low-Level DAS/ECG Cardiotachometer Demo Board

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

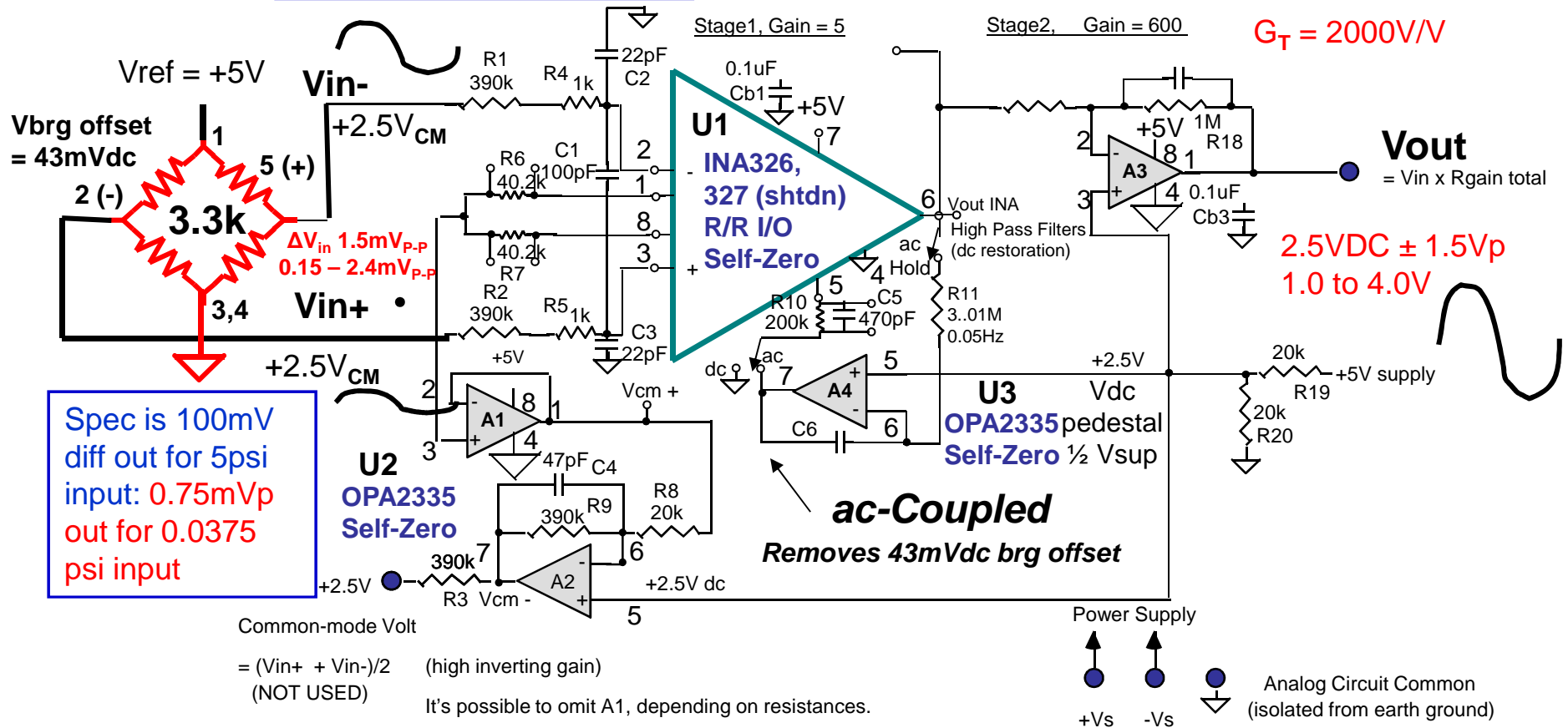
Quickly Puffing on Tube

ac-Coupled



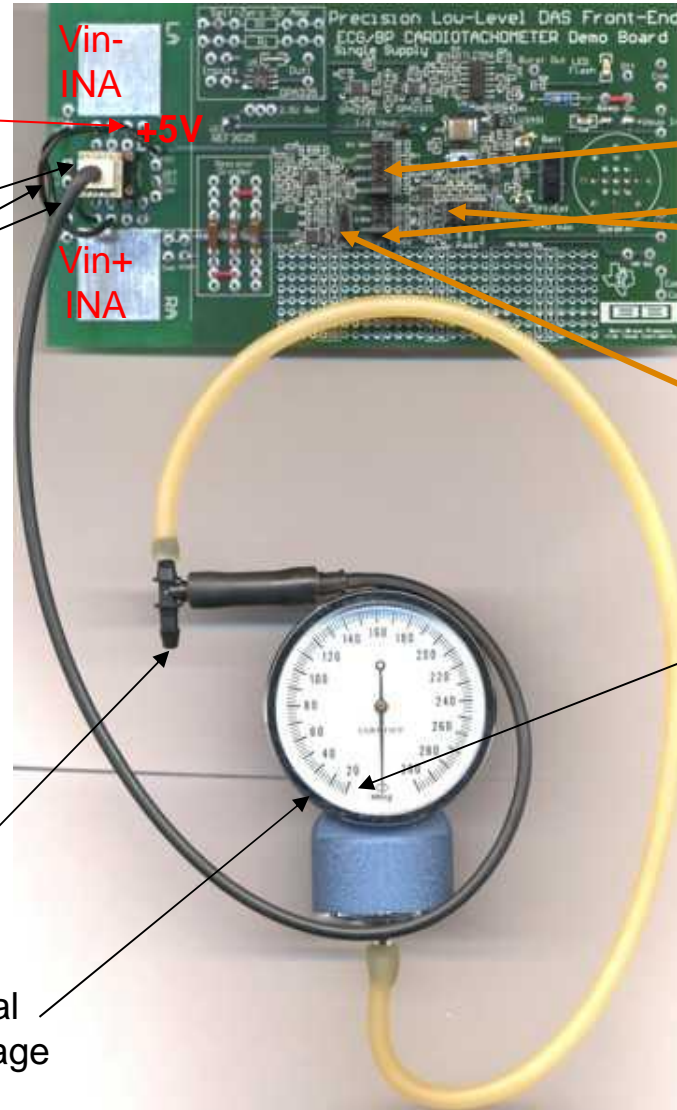
Low-Level DAS / ECG Cardiometer Demo Board – Puffing Pressure Bridge

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





Low-Level DAS / ECG Cardi tachometer 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

Puffing Pressure Input

Mechanical Pressure Gage

Vin- INA
+5V
Vin+ INA

Gtotal = 2kV/V

2Hz to

17Hz BW

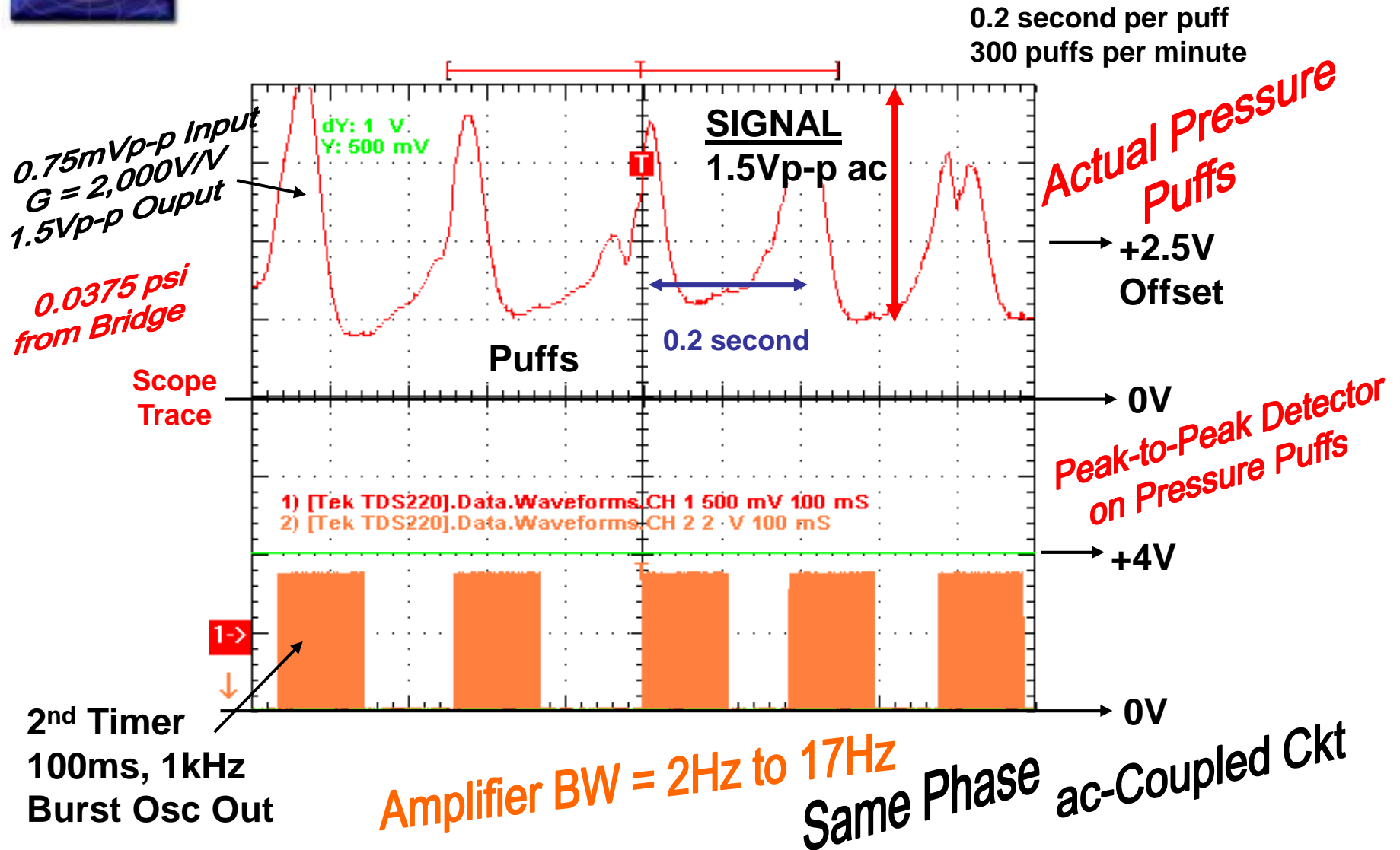
Plugged Into ac-Coupled Position

Δ5mmHg, Δ0.0375psi Change When Puffing

ac-Coupled
Same Phase

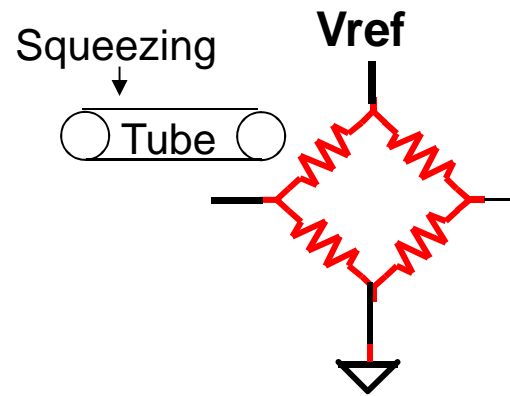


Low-Level DAS / ECG Cardi tachometer Demo Board – Puffing Pressure Bridge





A Precision Low-Level DAS/ECG Cardiotachometer Demo Board



Circuit Uses OPA336s
Instead of OPA335s

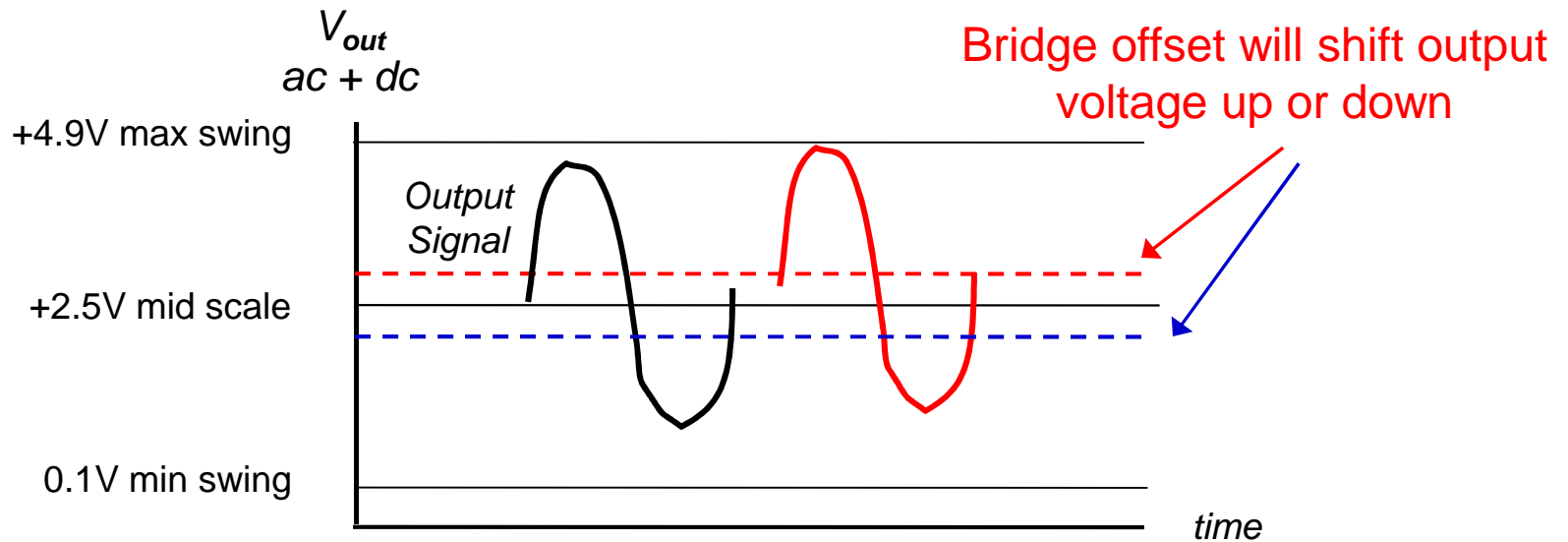
Pressure Bridge Application
Slowly Squeezing on Tube
dc-Coupled



A Precision Low-Level DAS/ECG Cardiotachometer Demo Board

dc-coupled

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

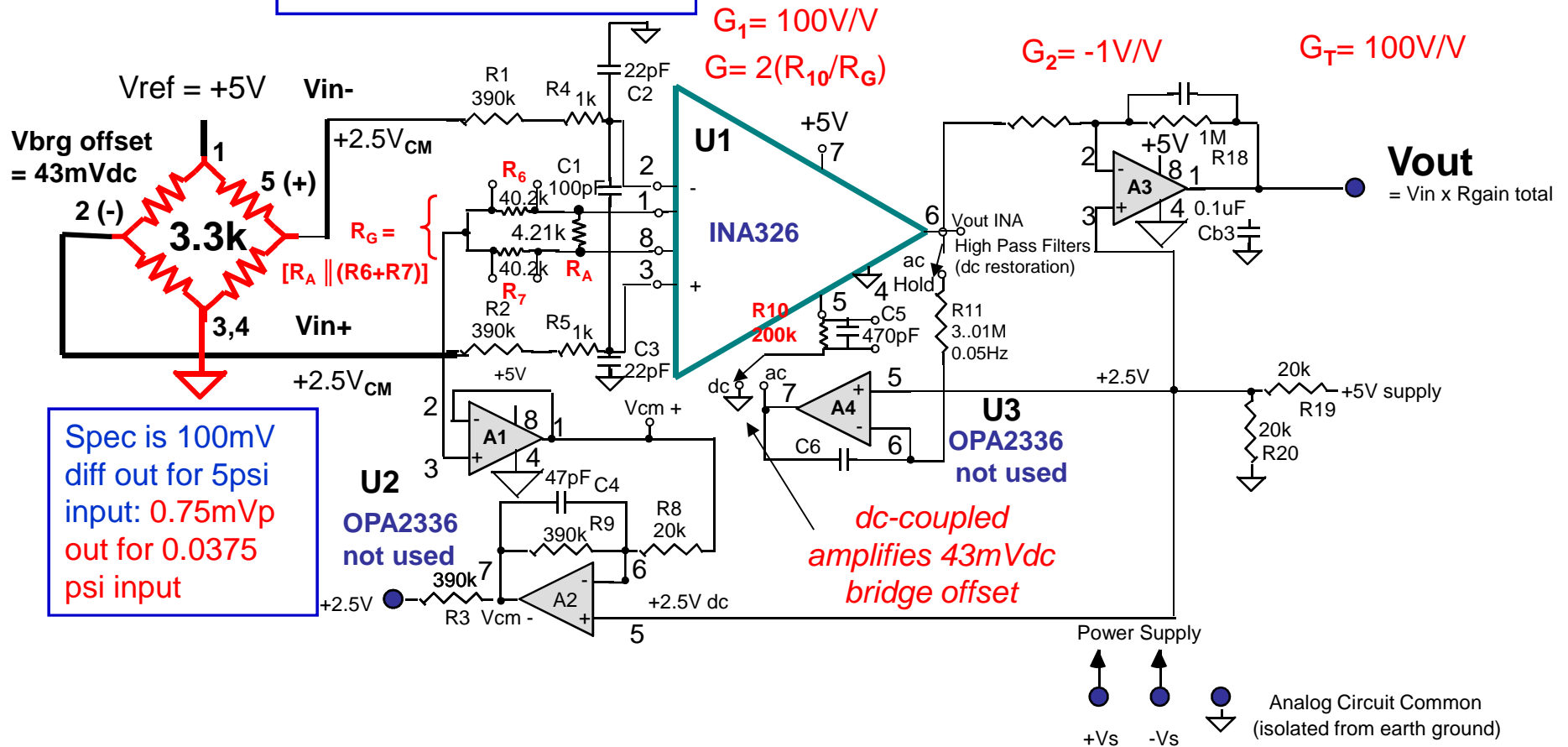


In single supply circuits, a mid-scale offset is used
with the amplifiers to assure linear operation.



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

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

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

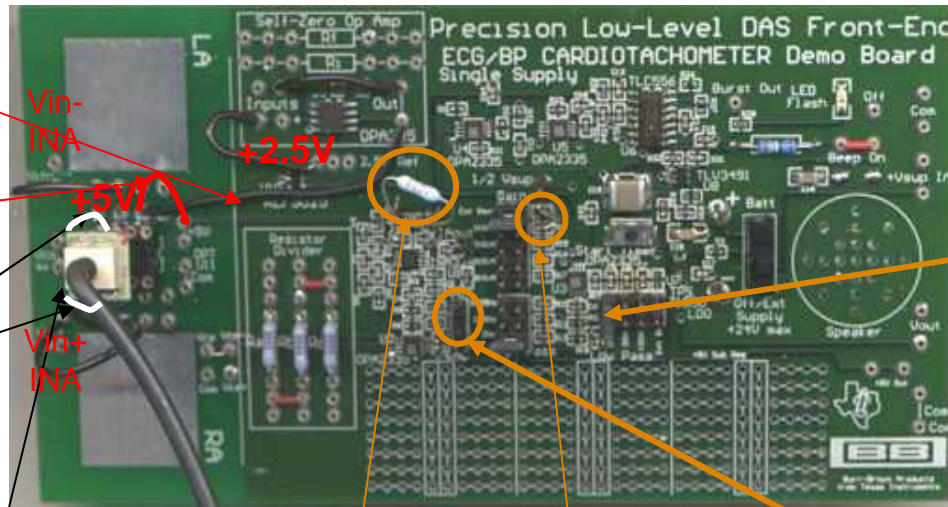
#1, +5V Excitation Directly From Sub Regulated Supply

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



INA326
 $R_G = 4.02k\Omega$

OPA336
 $R_F = 1M\Omega$

Gtotal = 100V/V dc

17Hz BW

Circuit Uses OPA336s Instead of OPA335s for Op Amps

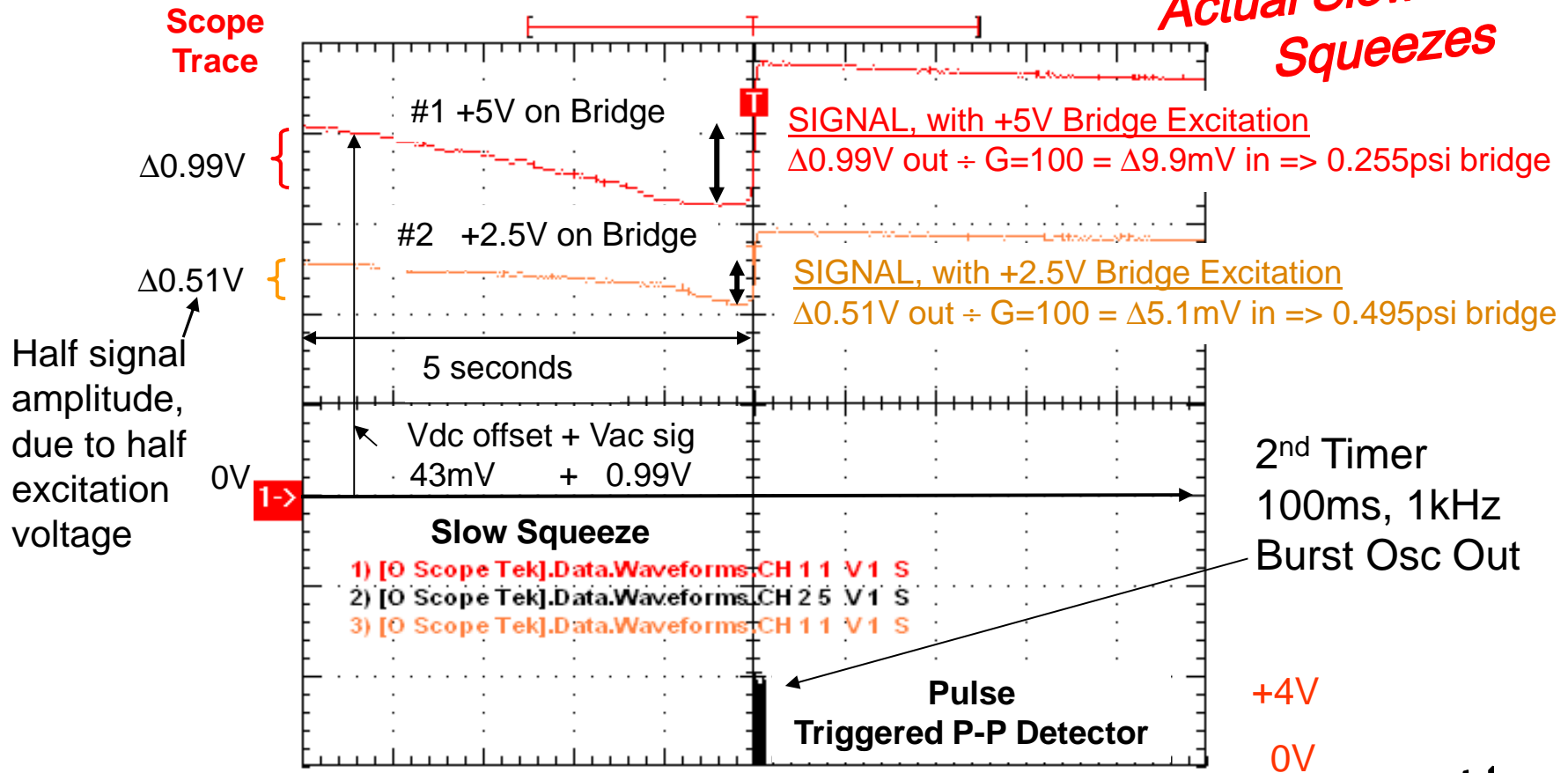
Plugged Into dc-Coupled Position

dc-Coupled
Opposite Phase



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

Actual Slow Pressure Squeezes



Amplifier BW = dc to 17Hz

Opposite Phase

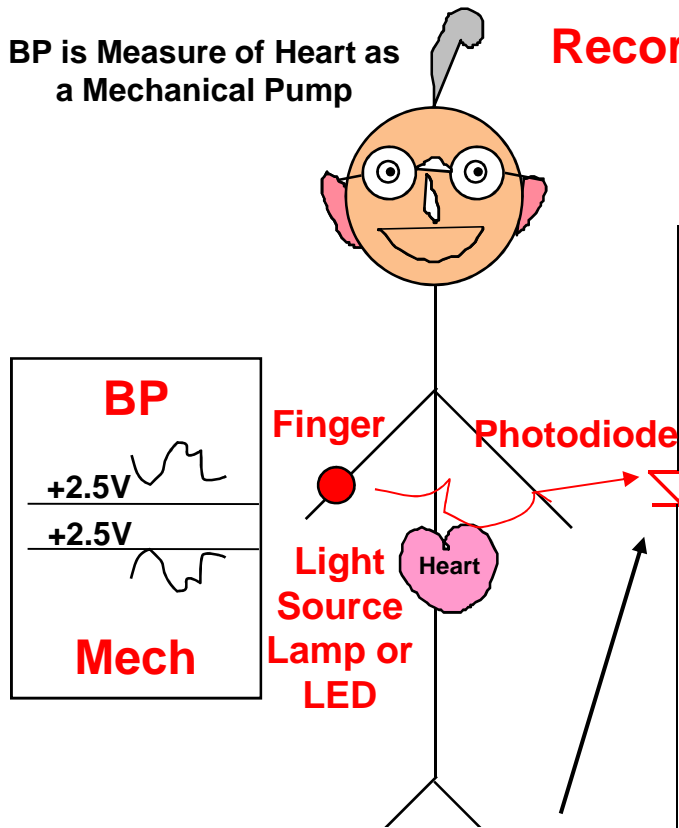
dc-Coupled Ckt



A Precision Low-Level DAS/ECG Cardiometer 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

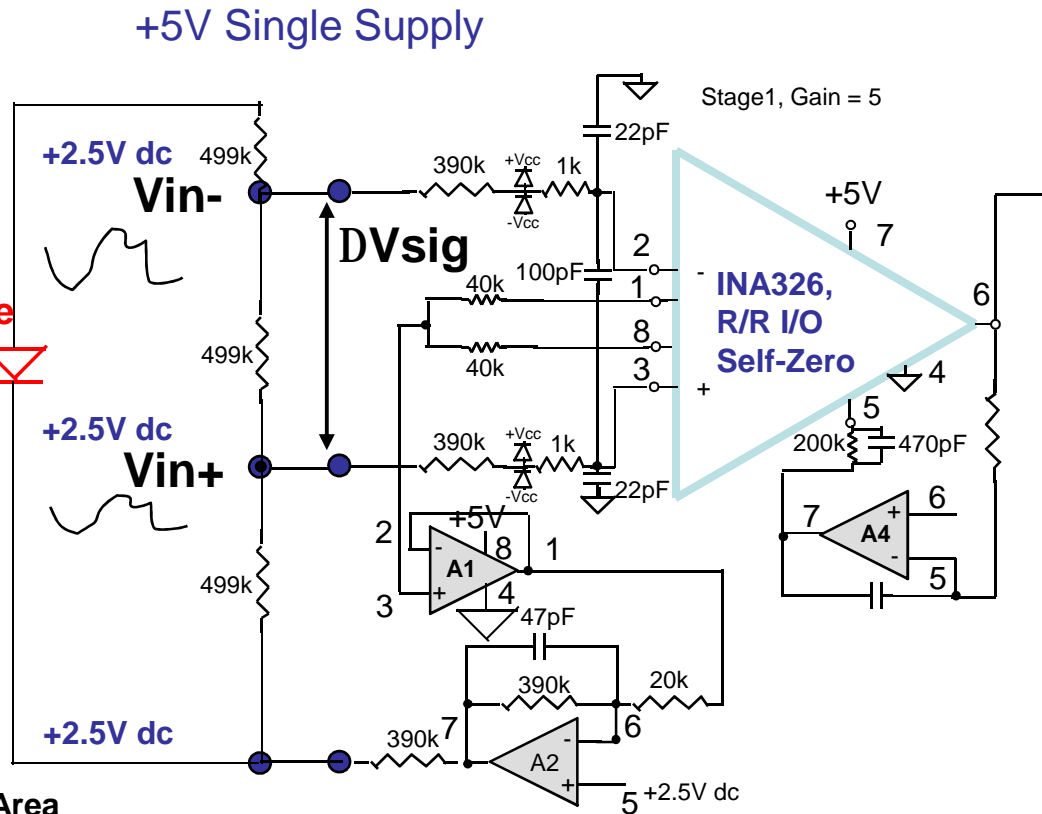


Photodiode Examples

Vishay/Telefunken BPW34, 7.5mm² Area

Hamamatsu S1227-BR, S2387-16R, 6.49mm² Area

TI OPT101, Just PD, 5.2mm² Area



(high inverting gain)
Right Leg Drive Amplifier

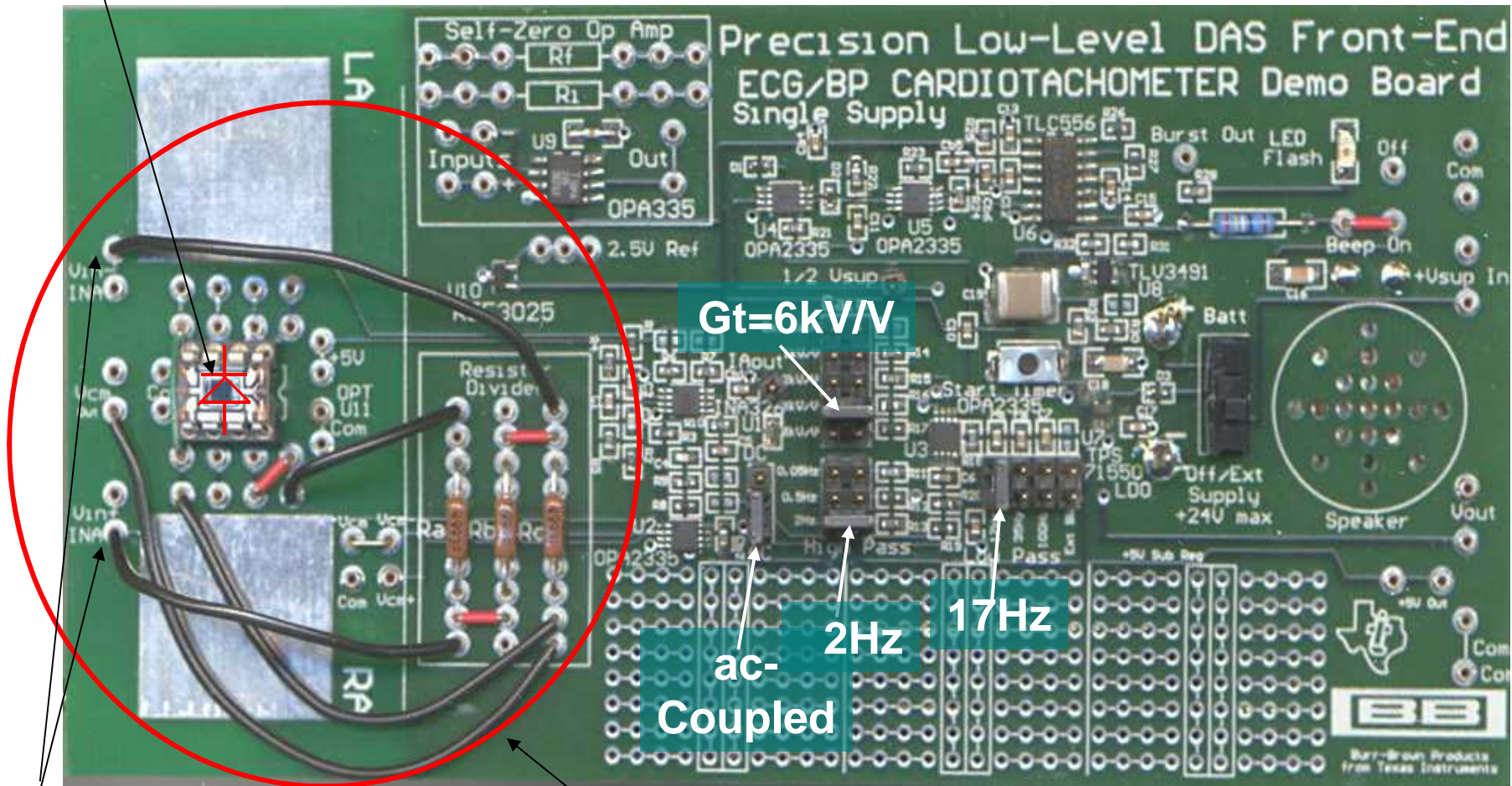
It's possible to omit A1, depending on resistances.



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

ac-Coupled

Photodiode Inside OPT101 (Can Use Separate Photodiode)



Differential Input Voltage

OPT101 Photodiode Connected to 3-R Divider to Create Differential Input Voltage



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.