Expt 7 – Instrumentation Amplifiers

Sep 24, 2021 (Friday)

EE 230 Analog Circuits Lab

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2021-22/I

Summary

A) Introduction

- Single-Opamp Difference Amplifiers (problems)

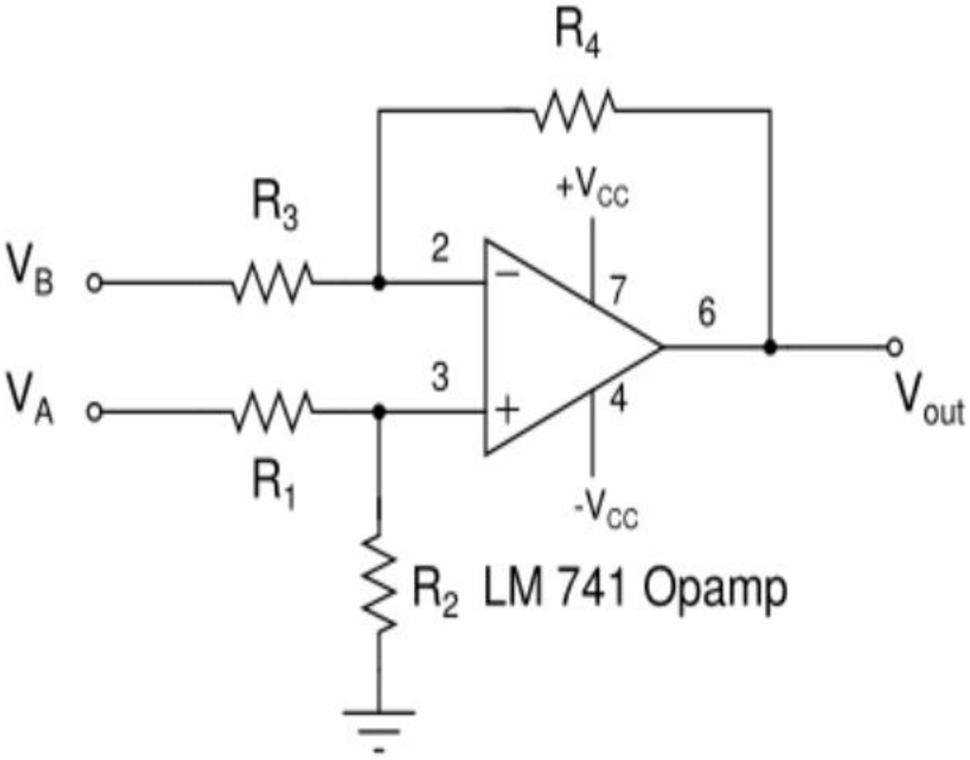
B) Three-Opamp Instrumentation Amplifiers

C) TL 084 Quad Opamps based Instrumentation Amplifier

D) INA 128 Instrumentation Amplifier

E) Loadcell and its Interfacing – using Instrumentation Amplifiers

Single-Opamp Difference Amplifier

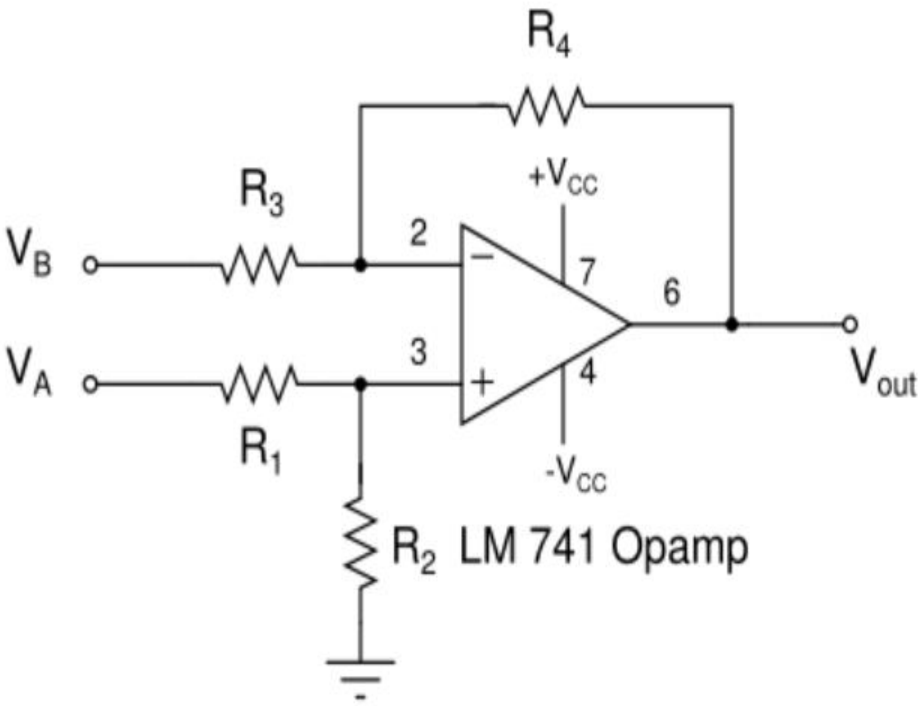


- Major Features
- Uses differential input signals

- Works as a difference amp if $(R_4/R_3 = R_2/R_1)$
- $A_d = V_{out}/(V_A - V_B) = R_4/R_3$
- $A_{cm} = 0$ (ideally)

- CMRR = A_d/A_{cm} (ideally ∞)

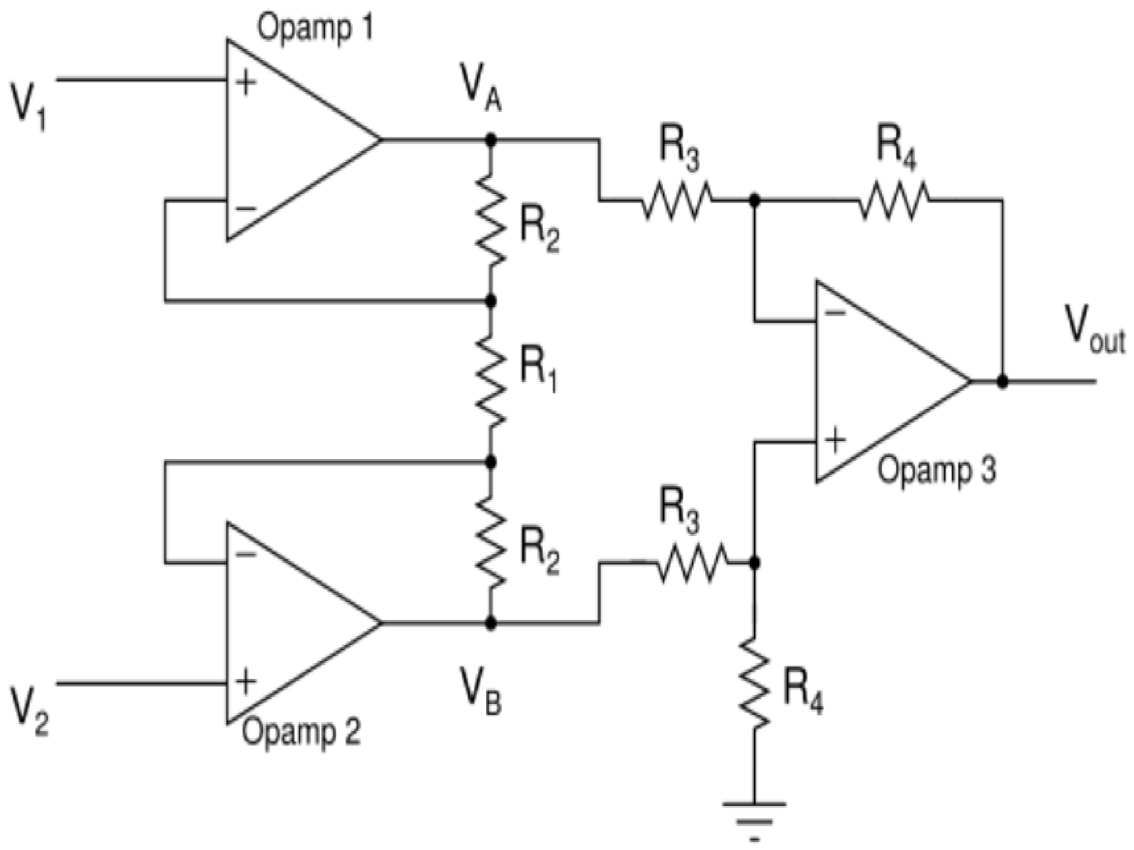
Problems of Single-Opamp Difference Amplifiers



Problems

- Difficult to change Ad
- Limited A_d
- Limited differential input resistance
- Limited CMRR (due to poor A_{cm})

B) Three-Opamp Instrumentation Amplifiers



Major features

- Very high input resistance

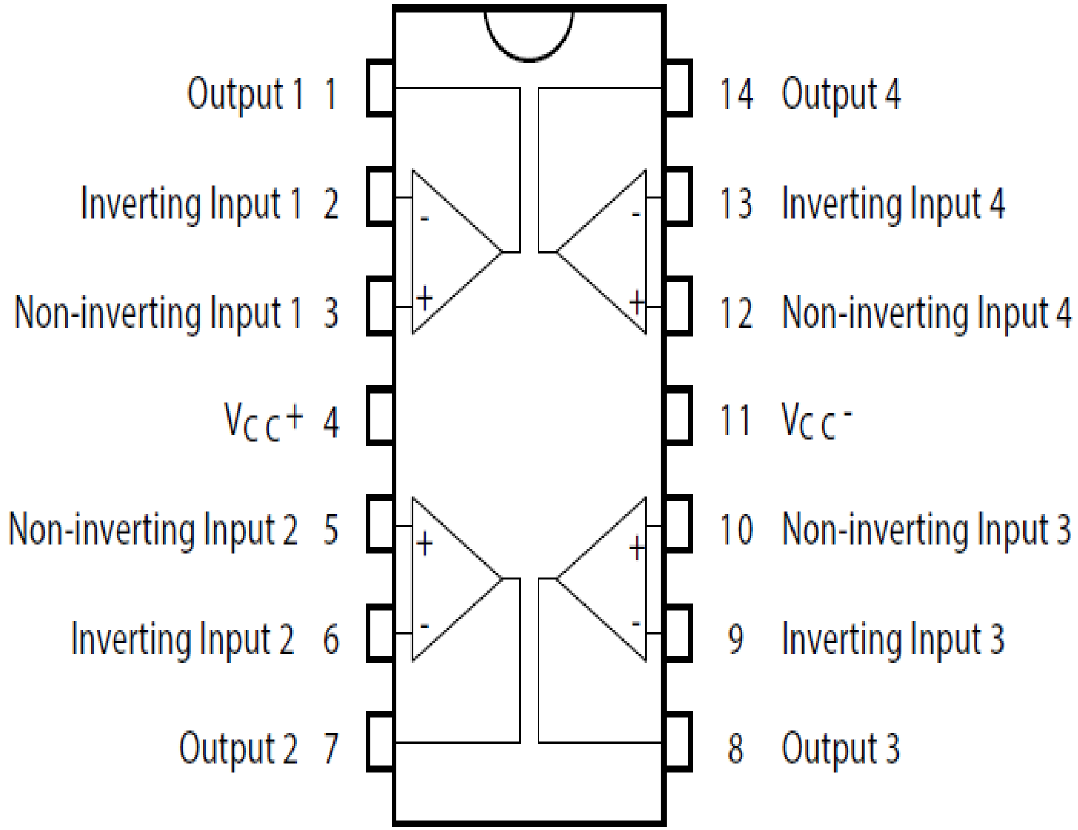
- Easy to change A_d

  $A_d = V_{out}/(V_2 - V_1)$

  $= (R_4/R_3)\,[1 + (2R_2/R_1)]$

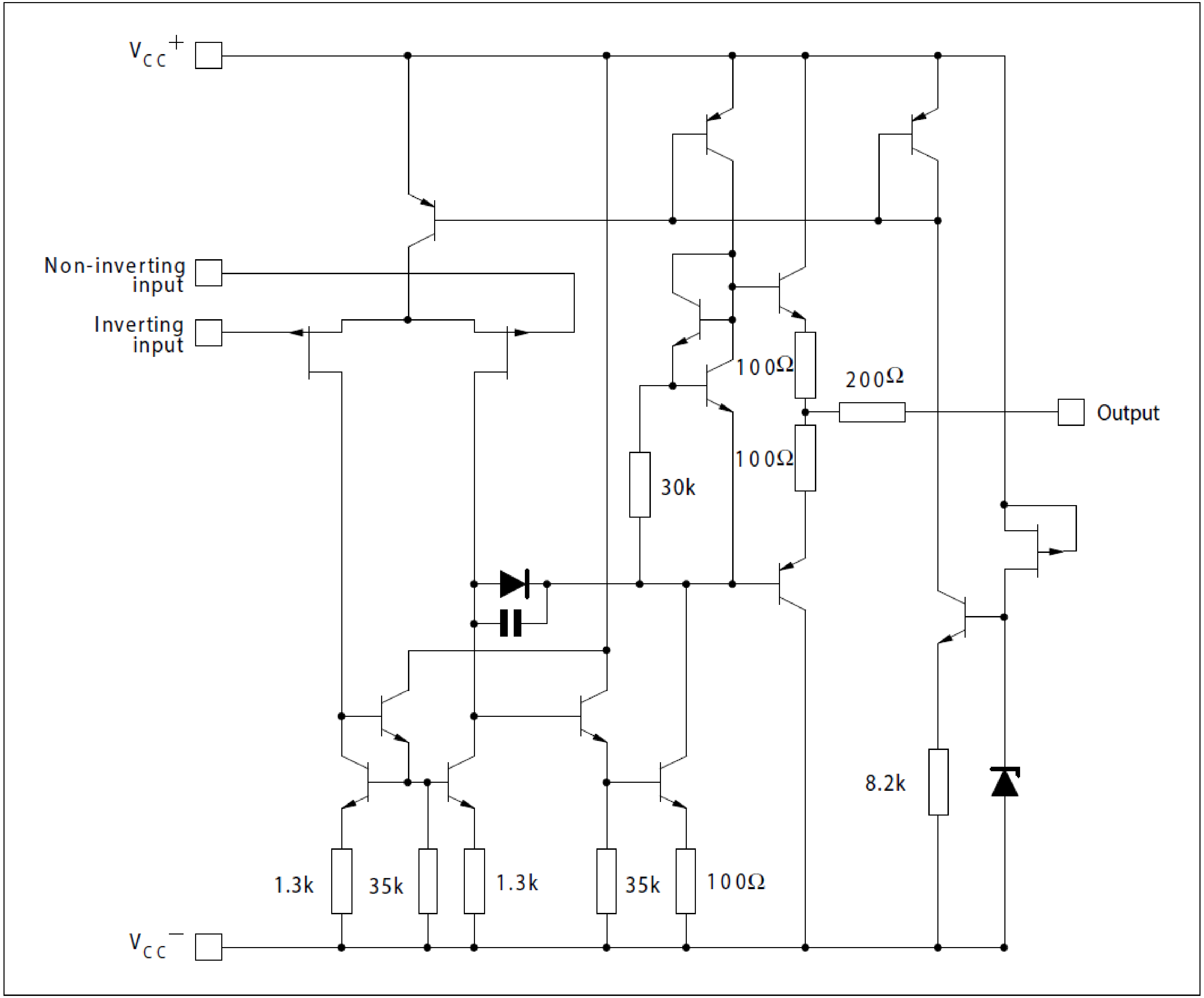
- Possible to have high Ad
- High CMRR

C) TL 084 Quad Opamps based Instrumentation Amplifier



TL 084 JFET Input Opamps

- Input offset voltage: 3 mv (typ)
- Input bias current: 20 pA
- CMRR: 86 dB
- Slew rate: 16 V/ µs
- GB product: 4 MHz

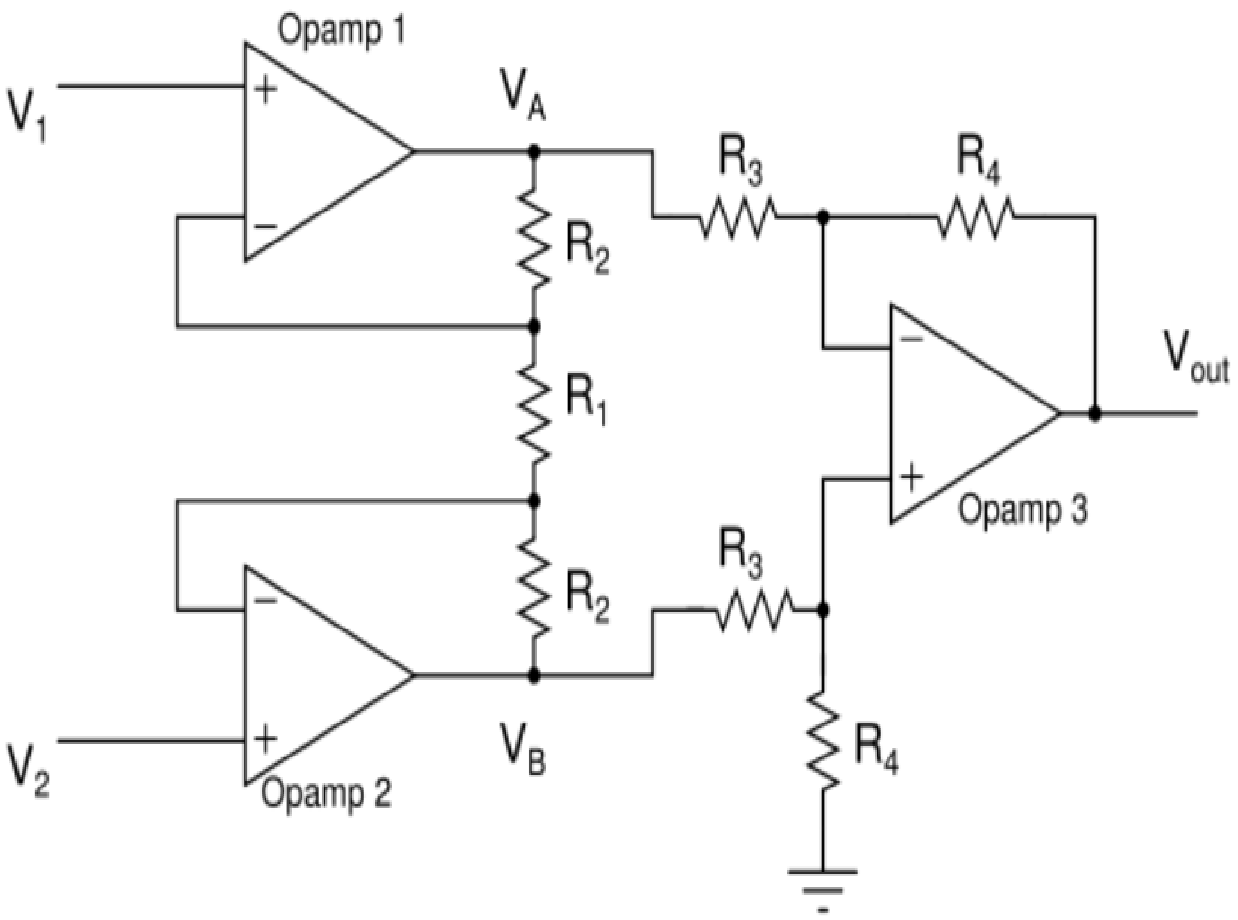


TL 084

- Circuit schematics (for each amplifier)

- Active loads
  - Used in all Opamps and other Linear ICs

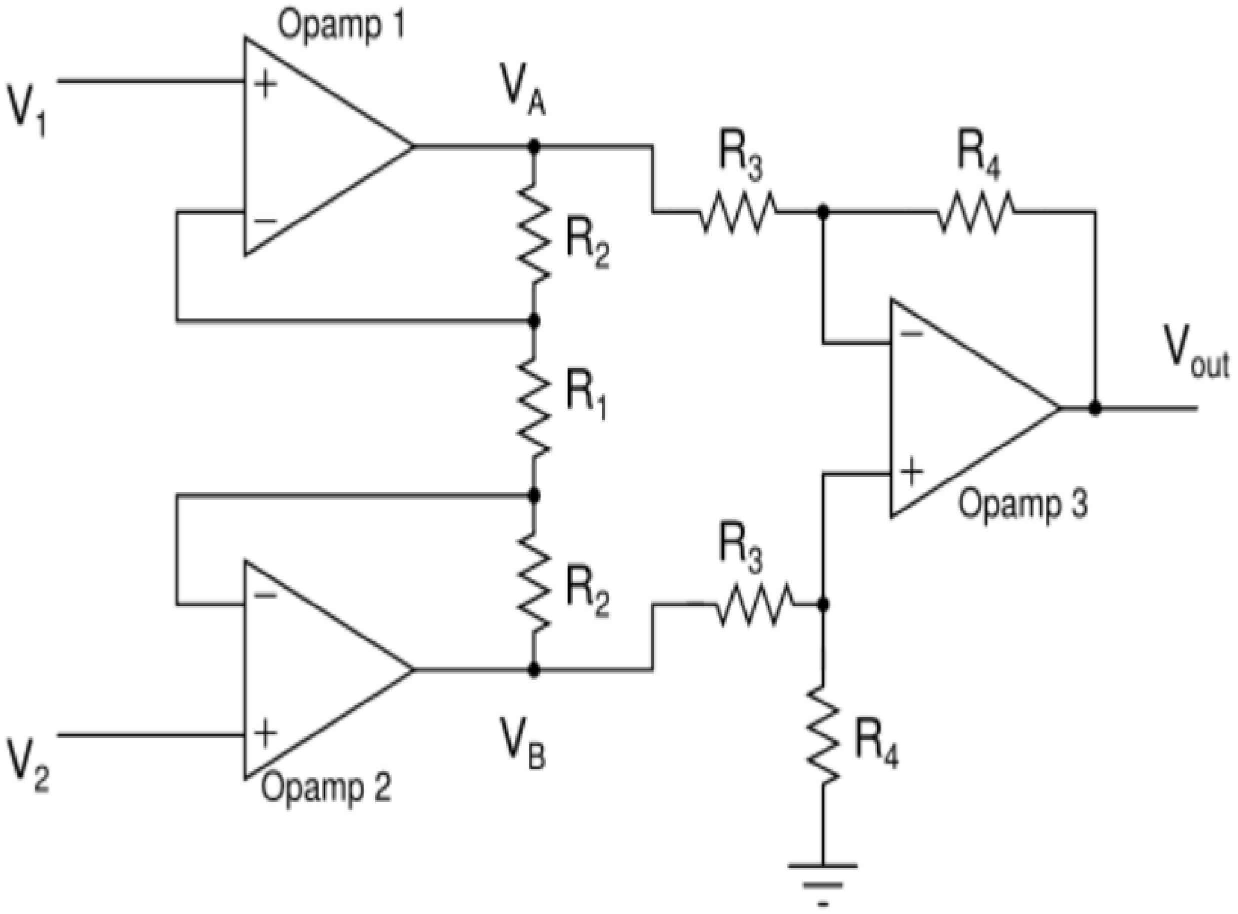
Three-Opamp Instrumentation Amplifier using TL084



+Vcc = 15 V

-Vcc = -15V

Measurement of the Common-mode Voltage Gain, A_{cm}



$V_1 = V_2 = 10 \sin \omega t$ V

Circuit values:

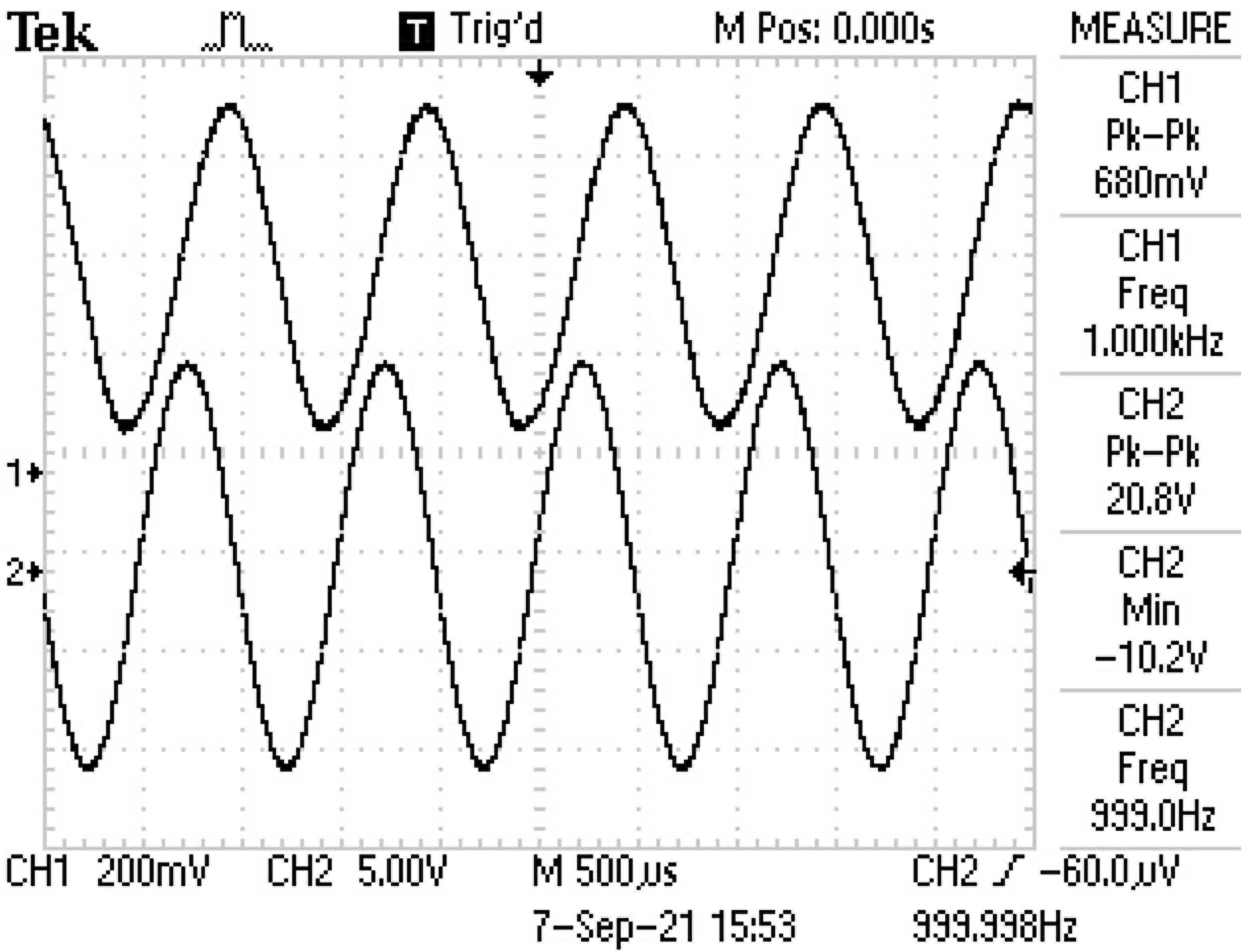
+Vcc = +15 V, -Vcc = -15 V,

$R_1 = R_2 = 10$ kΩ,

$R_3 = 1$ kΩ, and

R_4 (connected to the inverting input of Opamp 3) = 100 kΩ ;

R_4 (connected to the non-inverting input of Opamp 3) = 91 kΩ + 10 kΩ (Pot).



A_{cm} measurement

$V_1 = V_2 = 10 \sin \omega t$ V

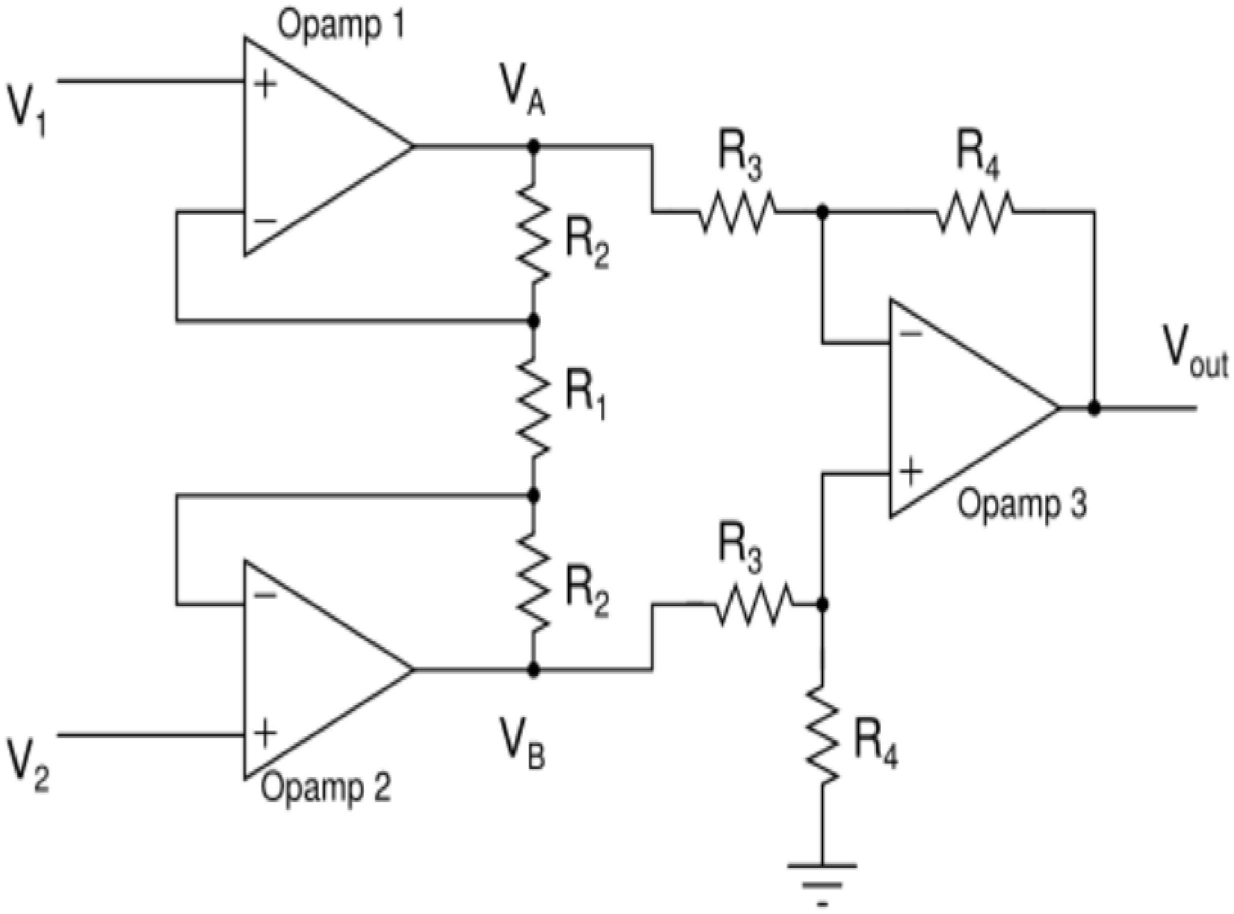
(20 Vp-p)

Vout : 680 mV

Acm = 0.034

(too high)

Measurement of the Differential Voltage Gain, A_d



$V_1 = 0$, $V_2 = 10 \sin \omega t$ mV

Circuit values:

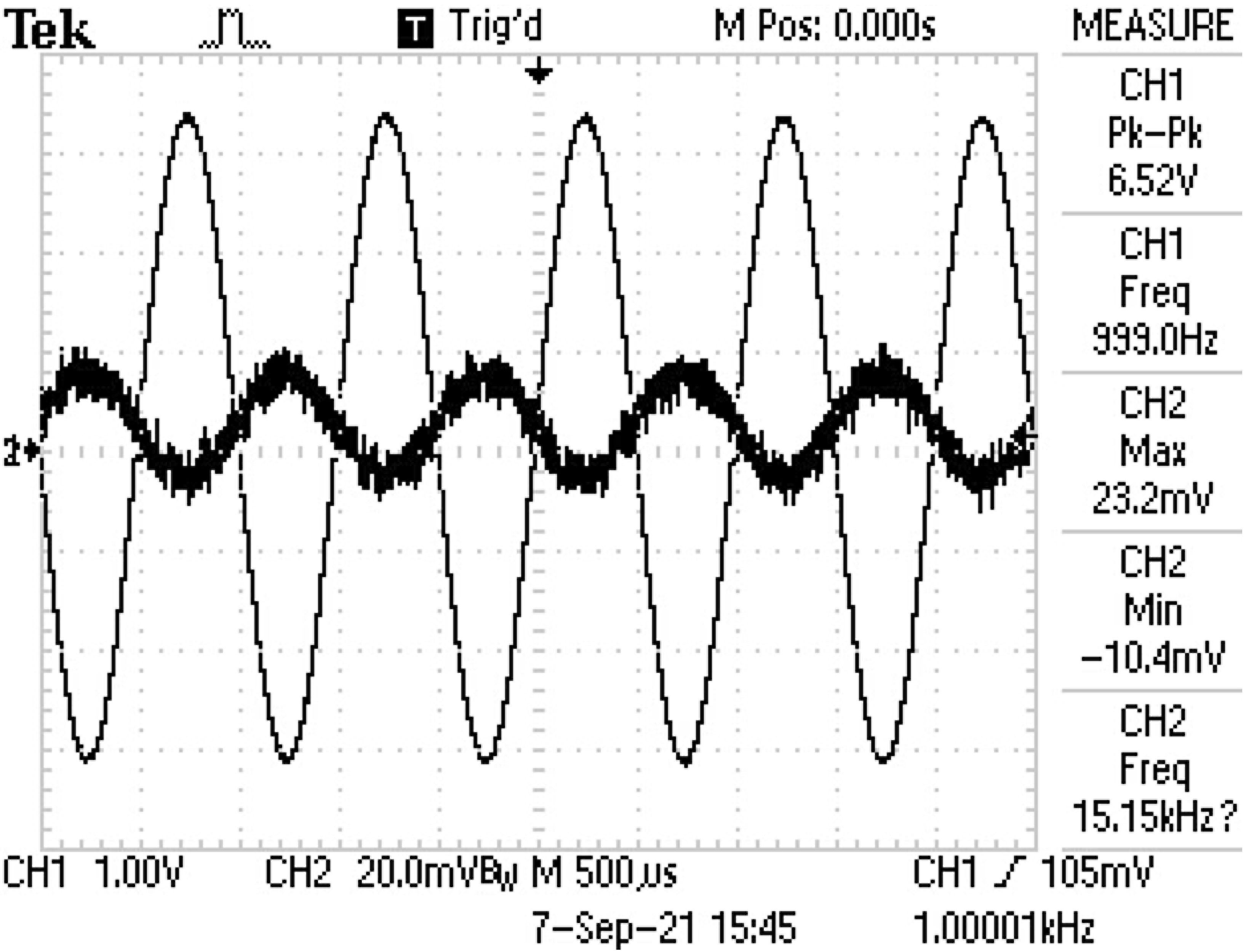
$+V_{cc} = +15$ V, $-V_{cc} = -15$ V,

$R_1 = R_2 = 10$ kΩ,

$R_3 = 1$ kΩ, and

R_4 (connected to the inverting input of Opamp 3) = 100 kΩ ;

R_4 (connected to the non-inverting input of Opamp 3) : adjusted for the lowest A_{cm}



A_d measurement

$V_1 = 0$

$V_2 = 10 \sin \omega t$ mV

(20 mV p-p)

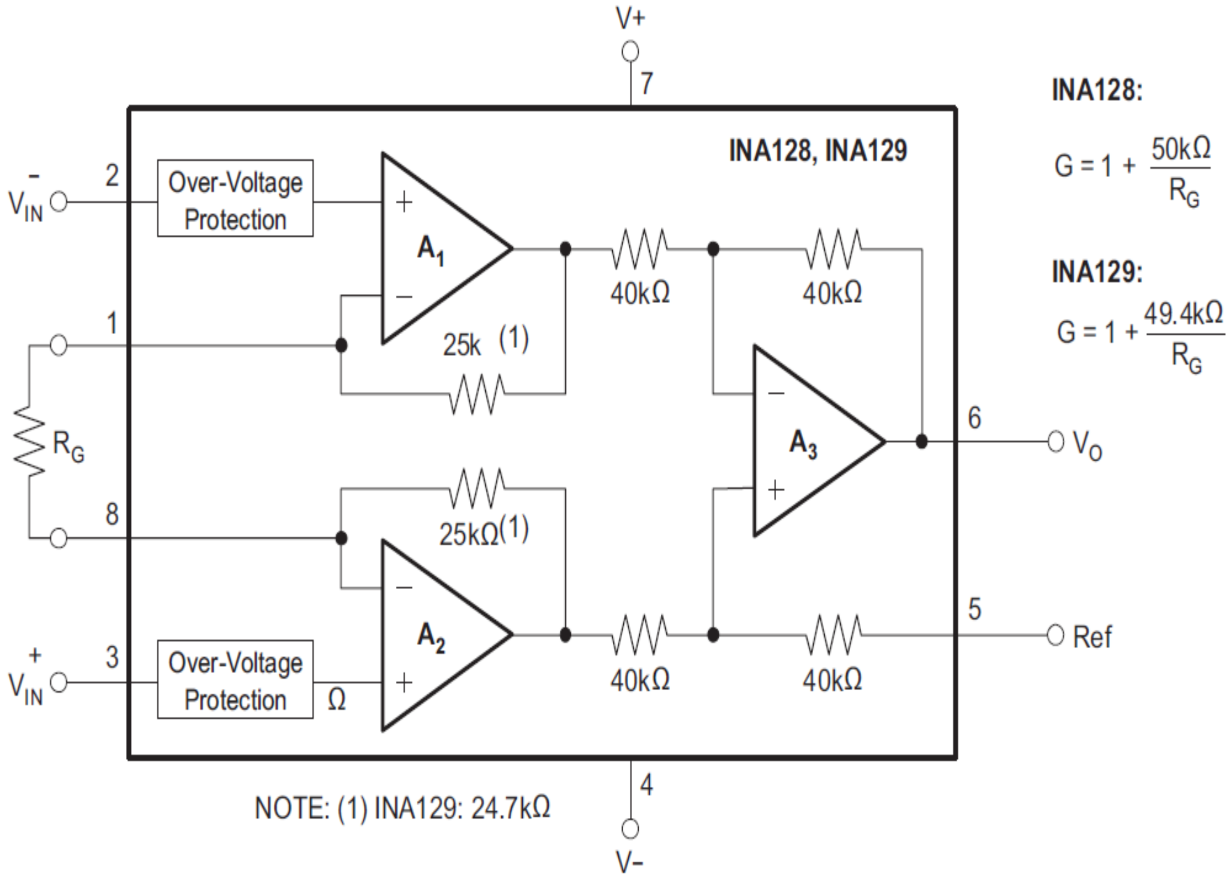
Vout : 6.5 Vp-p

$Ad = 6.52/0.02$

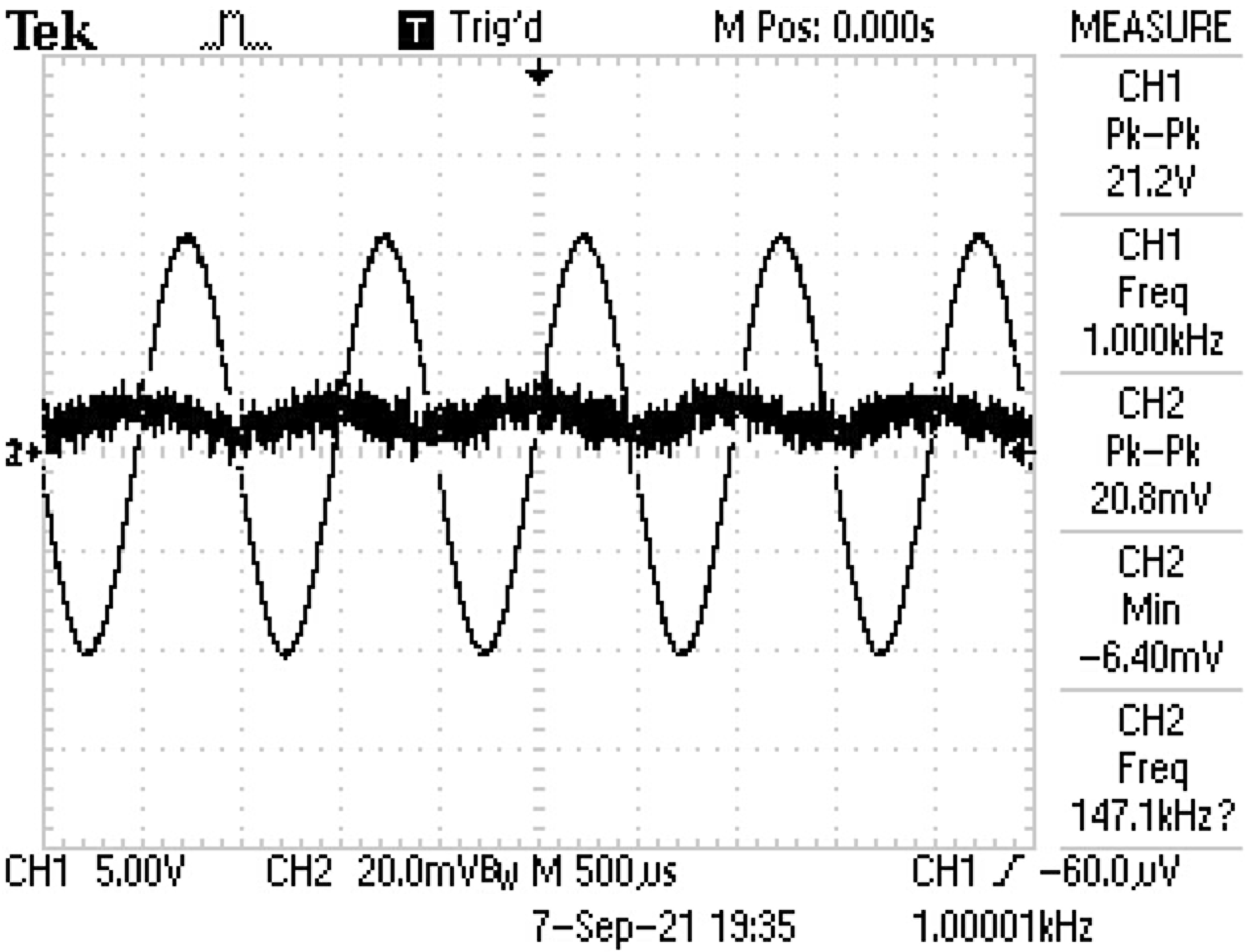
$= 326$

(As per design: 300)

D) INA 128 Instrumentation Amplifier



- A popular INA
- Applications:
  - Bridge amplifier
  - Thermocouple amplifier
  - RTD sensor amplifier
  - Medical instrumentation
  - Data acquisition
- Low offset voltage: 50 µV maximum
- Low drift: 0.5 µV/°C maximum
- Low Input Bias Current: 5 nA maximum
- High CMR: 120 dB minimum



A_{cm} measurement

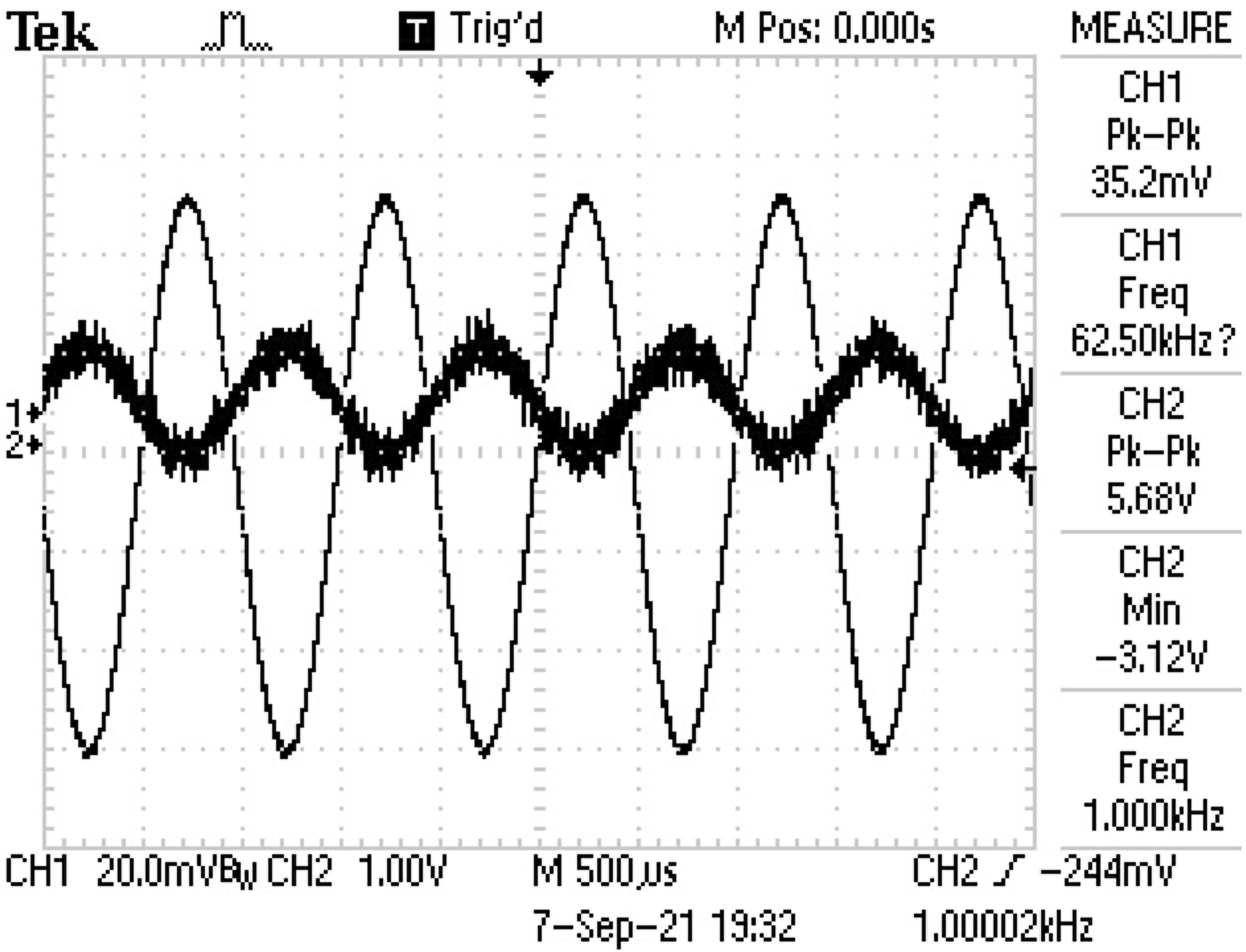
$V_1 = V_2 = 10 \sin \omega t$ V

(20 Vp-p)

Vout : 10 mV

Acm = 5×10^{-4}

(very good)



A_d measurement

$V_1 = 0$

$V_2 = 10 \sin \omega t$ mV

(20 mV p-p)

Vout : 5.68 Vp-p

Ad = 5.68/0.02

= 284

(As per design:
[1+(50k/0.18) = 279]

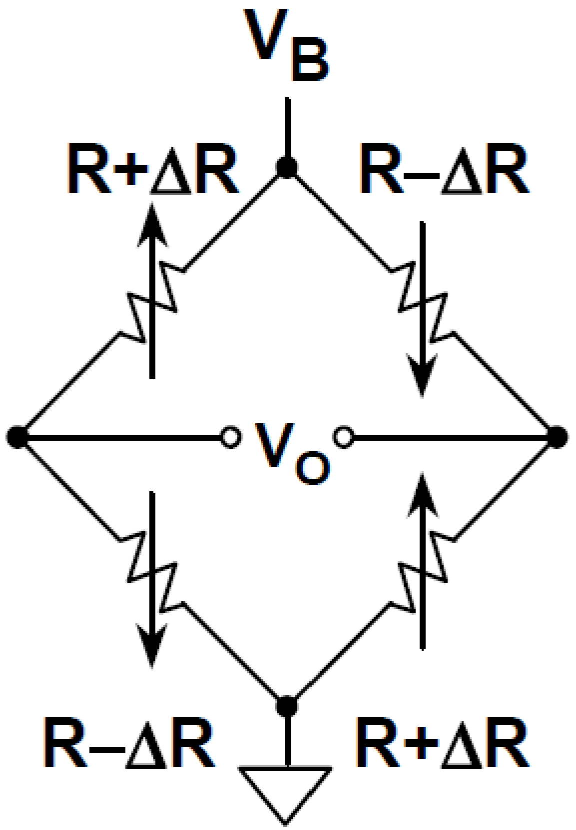
Measured CMRR:

$(284/5\text{x}10^{-4}) = 568{,}000$
or 115 dB

E) Loadcell and its Interfacing – using Instrumentation Amplifiers

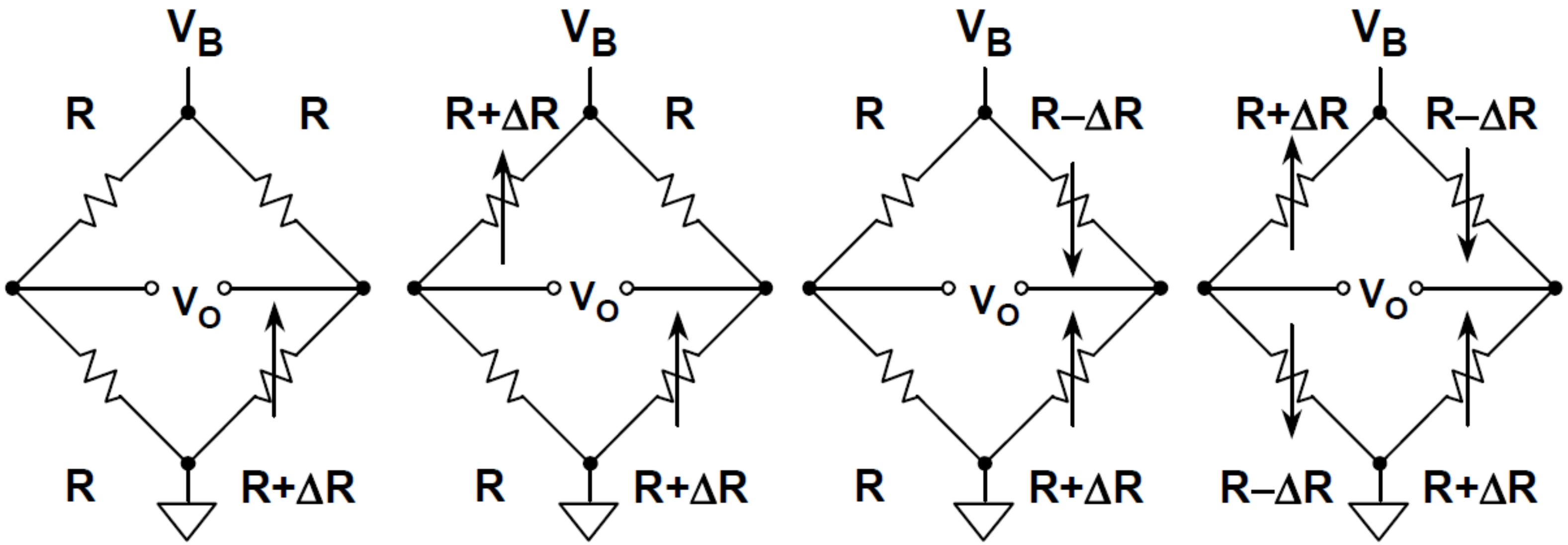
- **Load Cell**
- A commonly used sensor for measuring weight/pressure.

- Uses a full-bridge strain gage network (i.e. a Wheatstone bridge made of four strain gages)



Source: Sec 4-2, Sensor Signal Conditioning – Bridge Circuits, Walt Kester

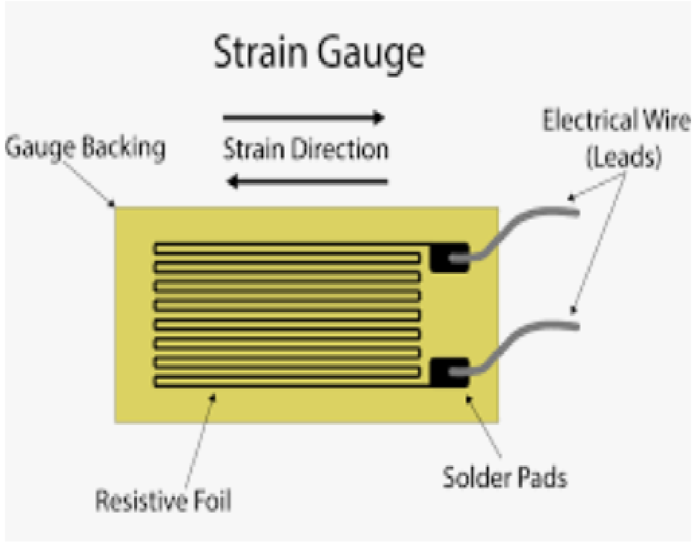
Output voltage sensitivity and linearity of constant voltage drive bridge configurations

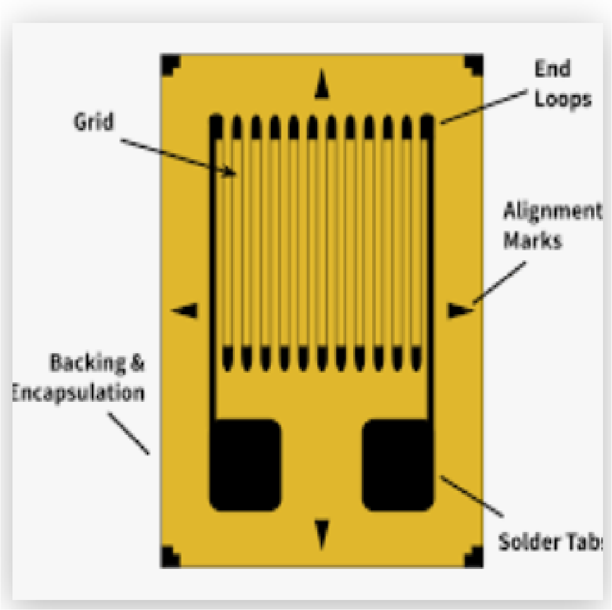


V_O:	$\frac{V_B}{4}\left[\frac{\Delta R}{R+\frac{\Delta R}{2}}\right]$	$\frac{V_B}{2}\left[\frac{\Delta R}{R+\frac{\Delta R}{2}}\right]$	$\frac{V_B}{2}\left[\frac{\Delta R}{R}\right]$	$V_B\left[\frac{\Delta R}{R}\right]$
Linearity Error:	0.5%/%	0.5%/%	0	0
	(A) Single-Element Varying	(B) Two-Element Varying (1)	(C) Two-Element Varying (2)	(D) All-Element Varying

Source: Sec 4-2, Sensor Signal Conditioning – Bridge Circuits, Walt Kester

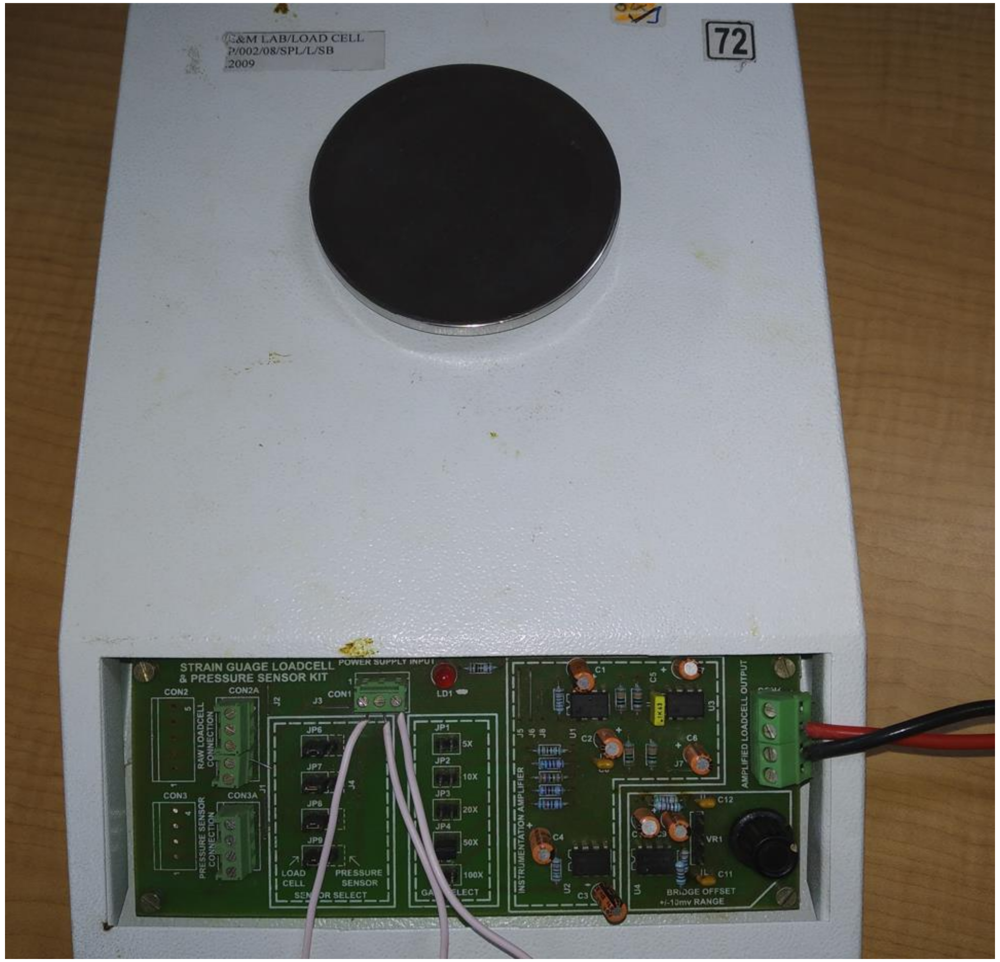
Strain Gages

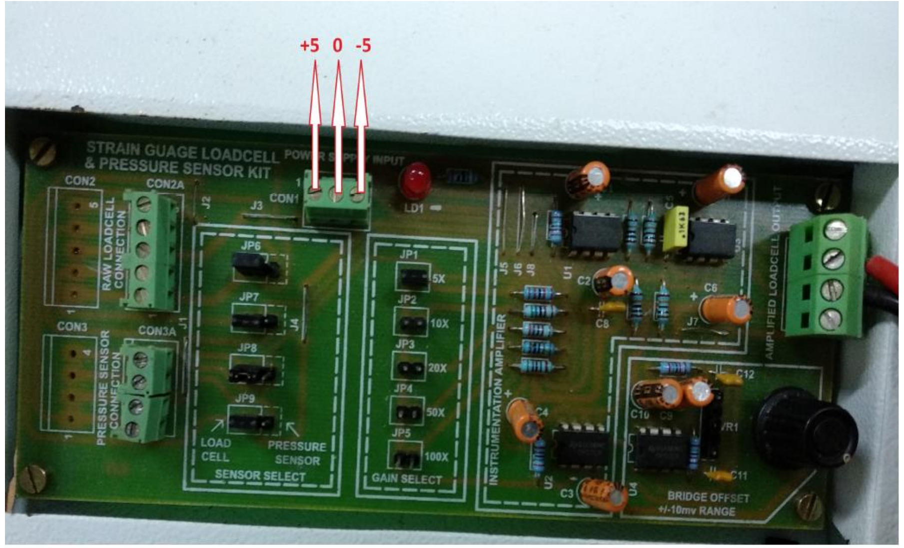


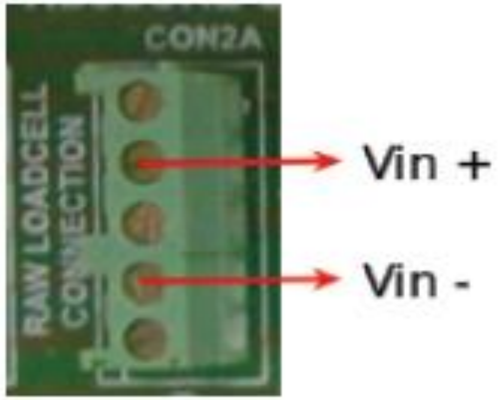


Strain gages (Source: Internet)

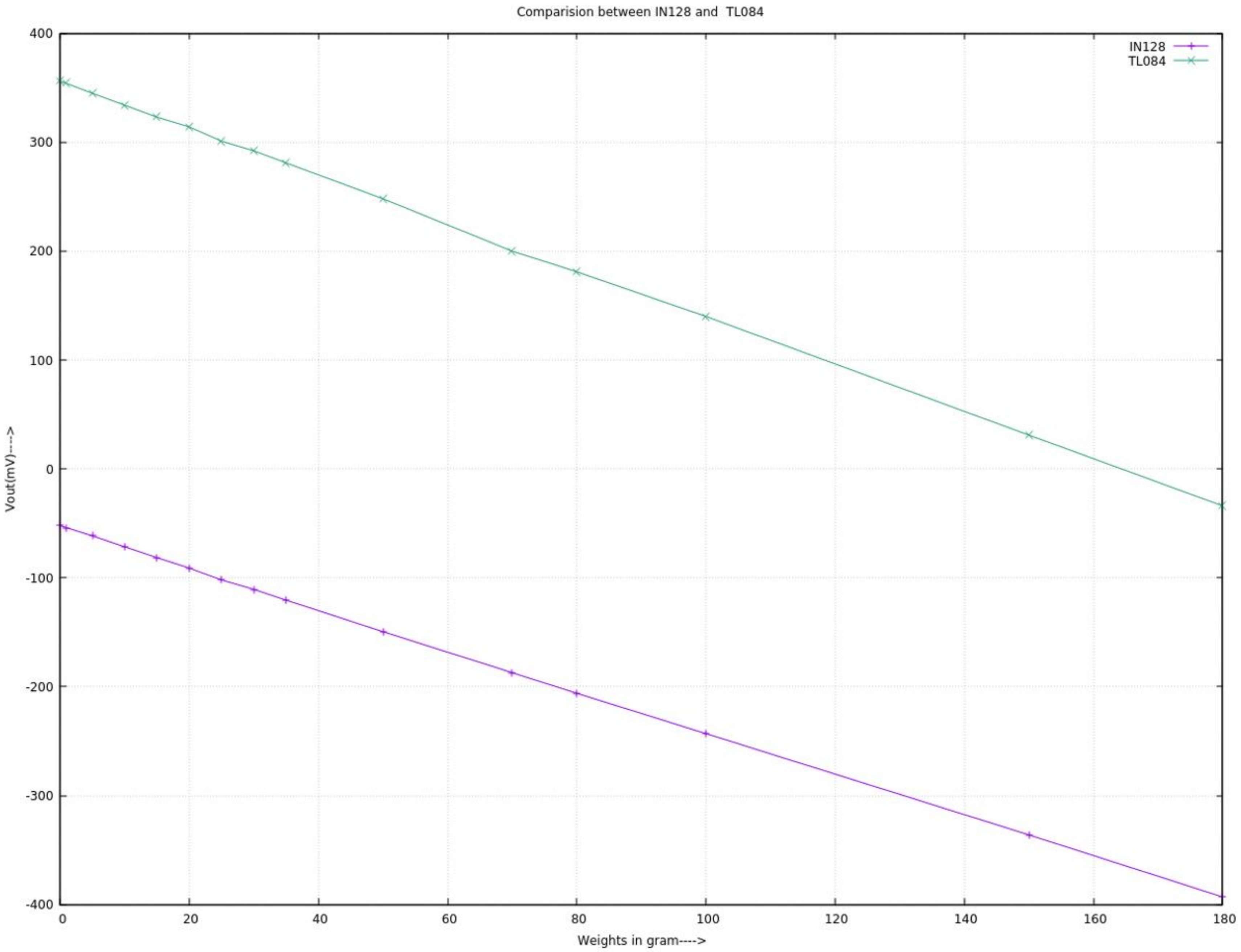
- Strain Gages
  - 120 Ω, 350 Ω, 3500 Ω
- Weigh-Scale Load Cells: 350 to 3500 Ω







Loadcell for Weight Measurement



- Output of Loadcell interface circuit:
- Comparison - INA128 vs TL084 based Instrumentation Amplifier