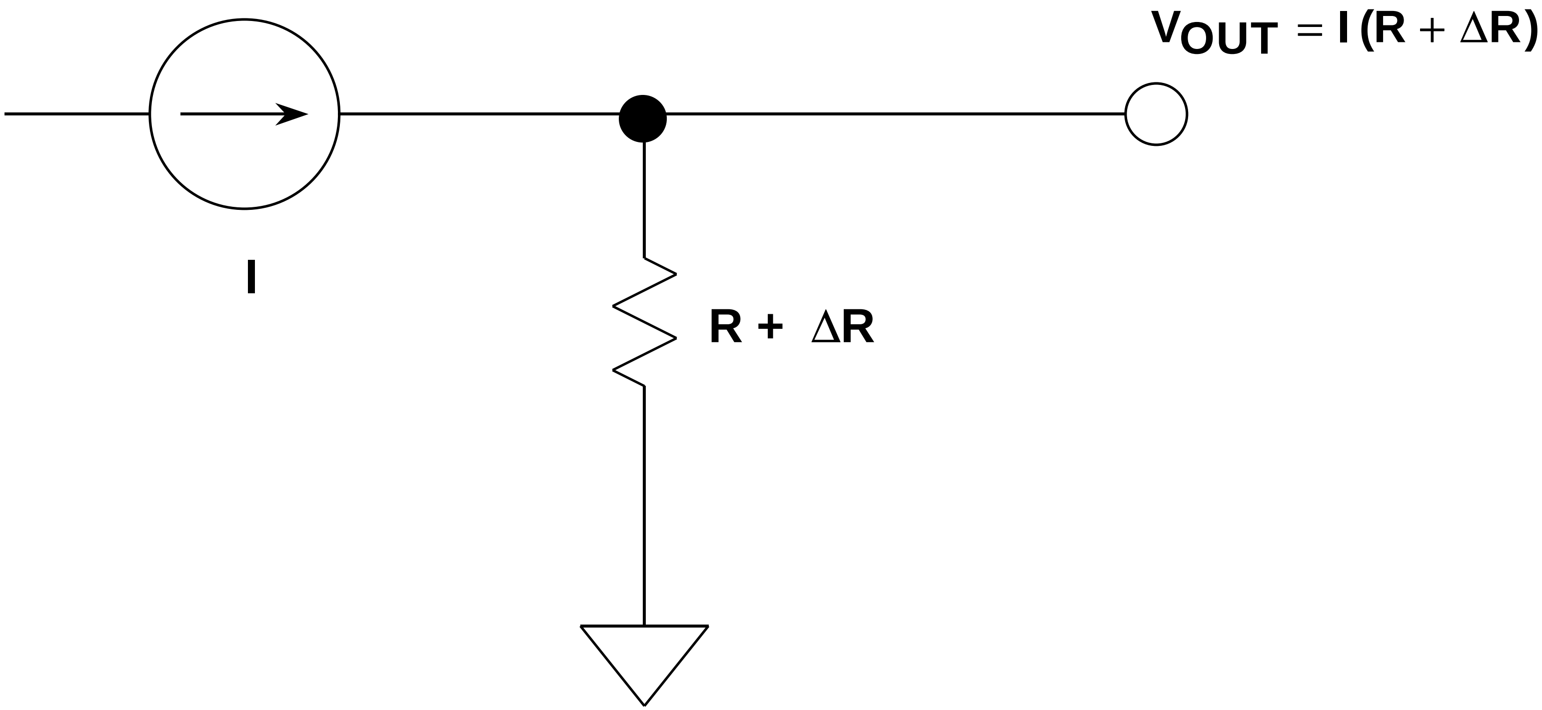
PRACTICAL DESIGN TECHNIQUES FOR SENSOR SIGNAL CONDITIONING

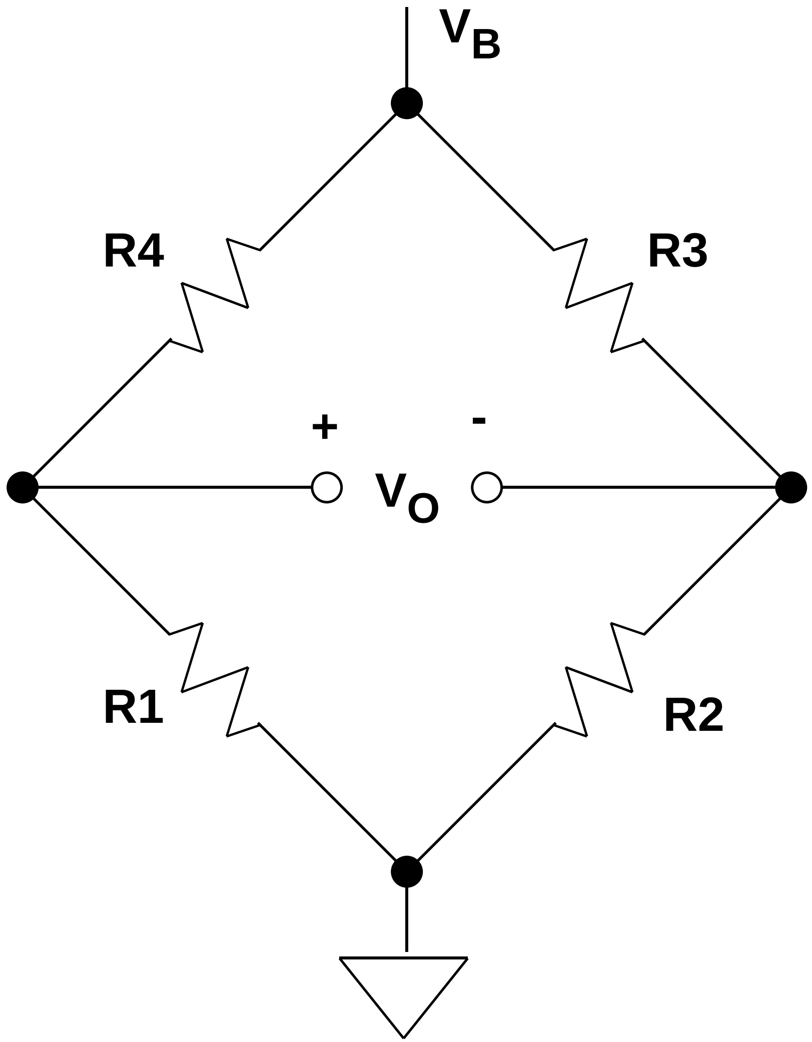
RESISTANCE OF POPULAR SENSORS

■ Strain Gages	120Ω, 350Ω, 3500Ω
■ Weigh-Scale Load Cells	350Ω - 3500Ω
■ Pressure Sensors	350Ω - 3500Ω
■ Relative Humidity	100kΩ - 10MΩ
■ Resistance Temperature Devices (RTDs)	100Ω , 1000Ω
■ Thermistors	100Ω - 10MΩ

MEASURING RESISTANCE INDIRECTLY USING A CONSTANT CURRENT SOURCE



THE WHEATSTONE BRIDGE



$$V_O = \frac{R1}{R1 + R4} V_B - \frac{R2}{R2 + R3} V_B$$

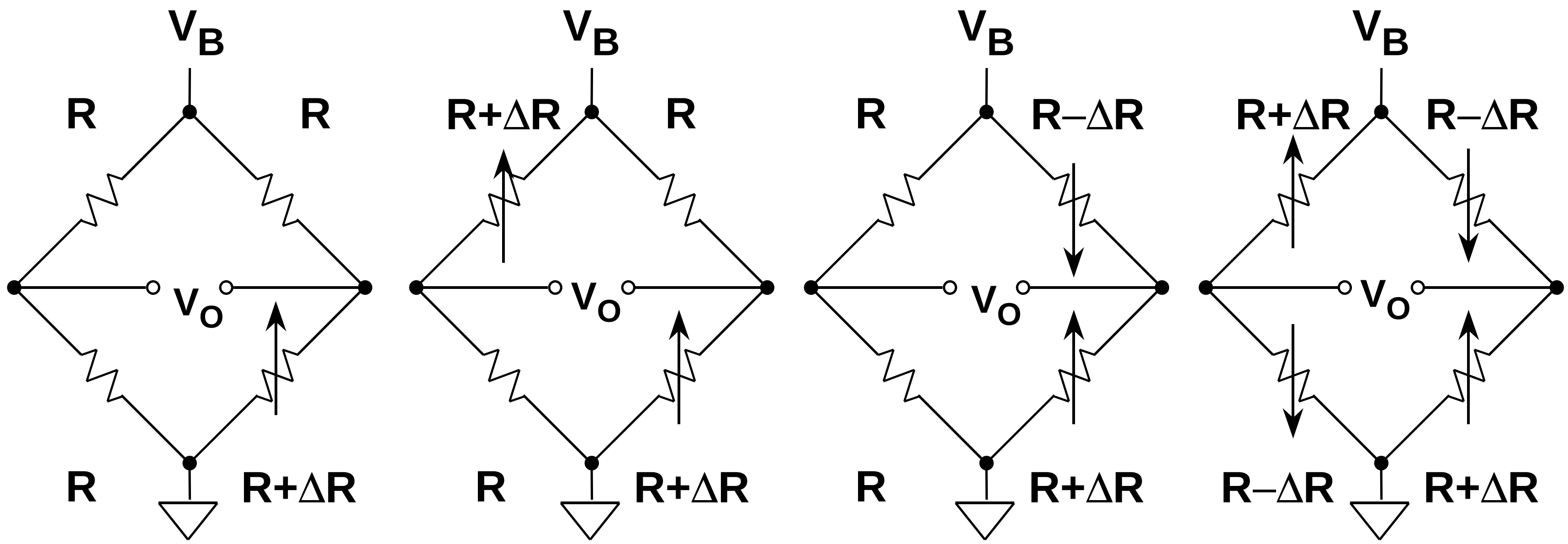
$$= \frac{\frac{R1}{R4} - \frac{R2}{R3}}{\left(1 + \frac{R1}{R4}\right)\left(1 + \frac{R2}{R3}\right)} V_B$$

AT BALANCE,

$$V_O = 0 \quad \text{IF} \quad \frac{R1}{R4} = \frac{R2}{R3}$$

a

OUTPUT VOLTAGE AND LINEARITY ERROR FOR CONSTANT VOLTAGE DRIVE BRIDGE CONFIGURATIONS



	(A)	(B)	(C)	(D)
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

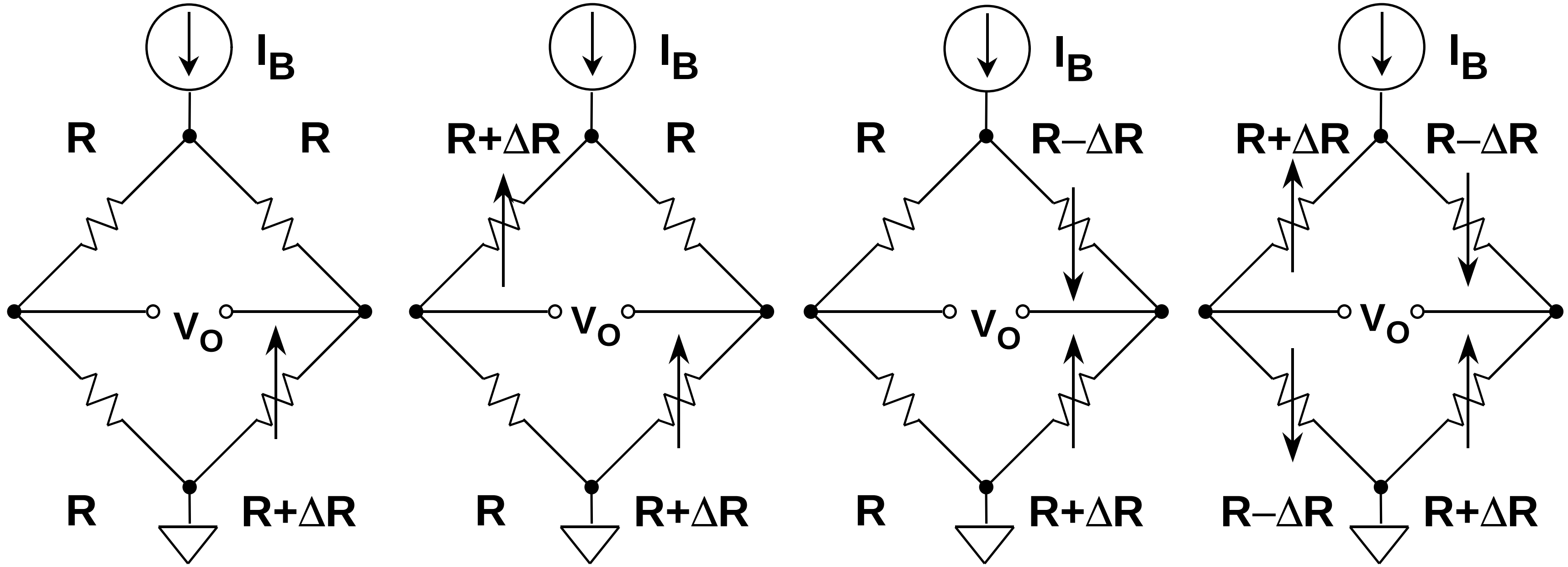
(B) Two-Element Varying (1)

(C) Two-Element Varying (2)

(D) All-Element Varying

a

OUTPUT VOLTAGE AND LINEARITY ERROR FOR CONSTANT CURRENT DRIVE BRIDGE CONFIGURATIONS

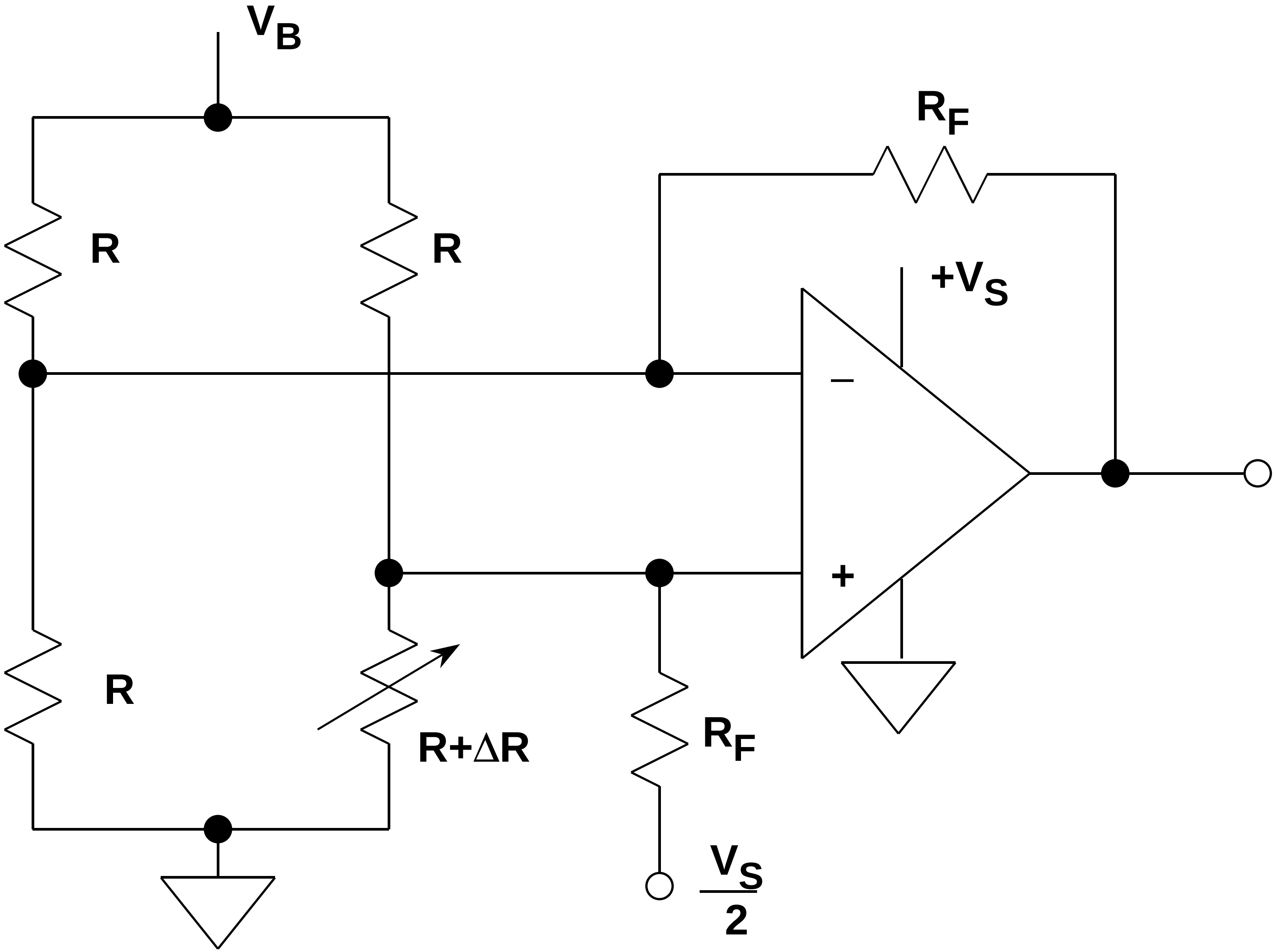


	(A) Single-Element Varying	(B) Two-Element Varying (1)	(C) Two-Element Varying (2)	(D) All-Element Varying
V_O:	$\frac{I_B R}{4}\left[\frac{\Delta R}{R + \frac{\Delta R}{4}}\right]$	$\frac{I_B}{2}\left[\Delta R\right]$	$\frac{I_B}{2}\left[\Delta R\right]$	$I_B\left[\Delta R\right]$
Linearity Error:	0.25%/%	0	0	0

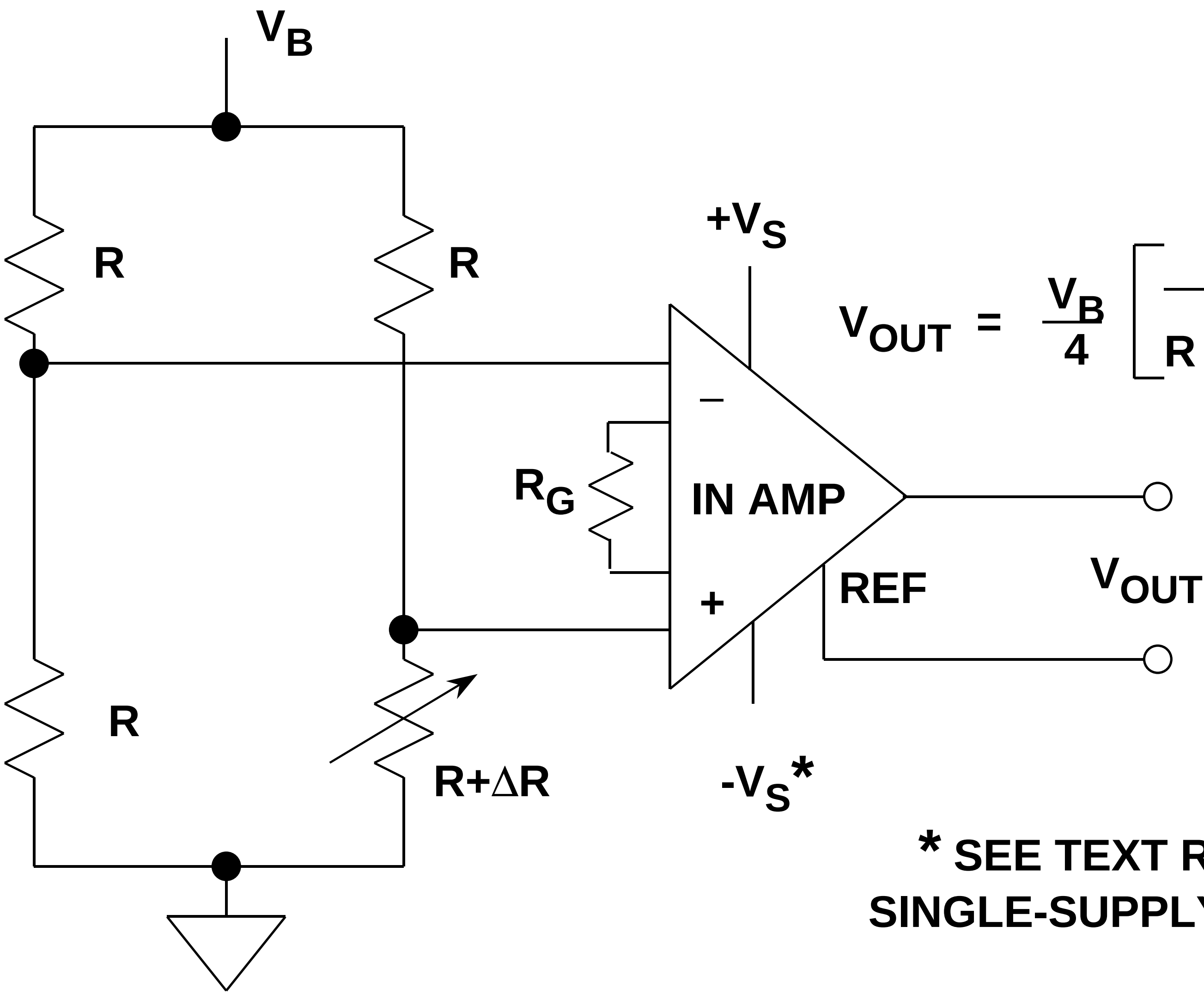
BRIDGE CONSIDERATIONS

- **Selecting Configuration (1, 2, 4 - Element Varying)**
- **Selection of Voltage or Current Excitation**
- **Stability of Excitation Voltage or Current**
- **Bridge Sensitivity: FS Output / Excitation Voltage**
  1mV / V to 10mV / V Typical
- **Fullscale Bridge Outputs: 10mV - 100mV Typical**
- **Precision, Low Noise Amplification / Conditioning**
  Techniques Required
- **Linearization Techniques May Be Required**
- **Remote Sensors Present Challenges**

USING A SINGLE OP AMP AS A BRIDGE AMPLIFIER FOR A SINGLE-ELEMENT VARYING BRIDGE



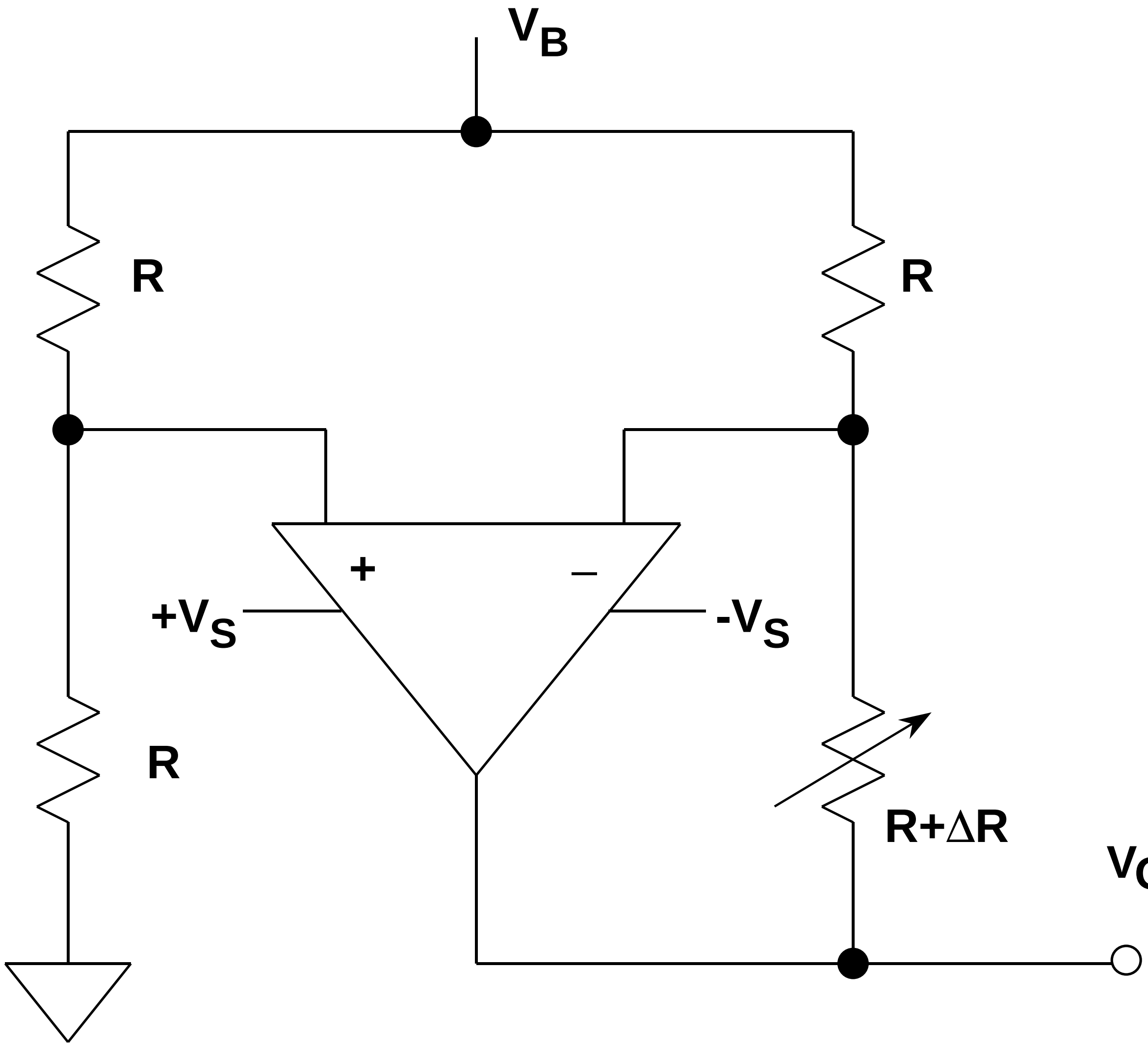
USING AN INSTRUMENTATION AMPLIFIER WITH A SINGLE-ELEMENT VARYING BRIDGE



$$V_{OUT} = \frac{V_B}{4}\left[\frac{\Delta R}{R + \frac{\Delta R}{2}}\right]\left[GAIN\right]$$

* SEE TEXT REGARDING SINGLE-SUPPLY OPERATION

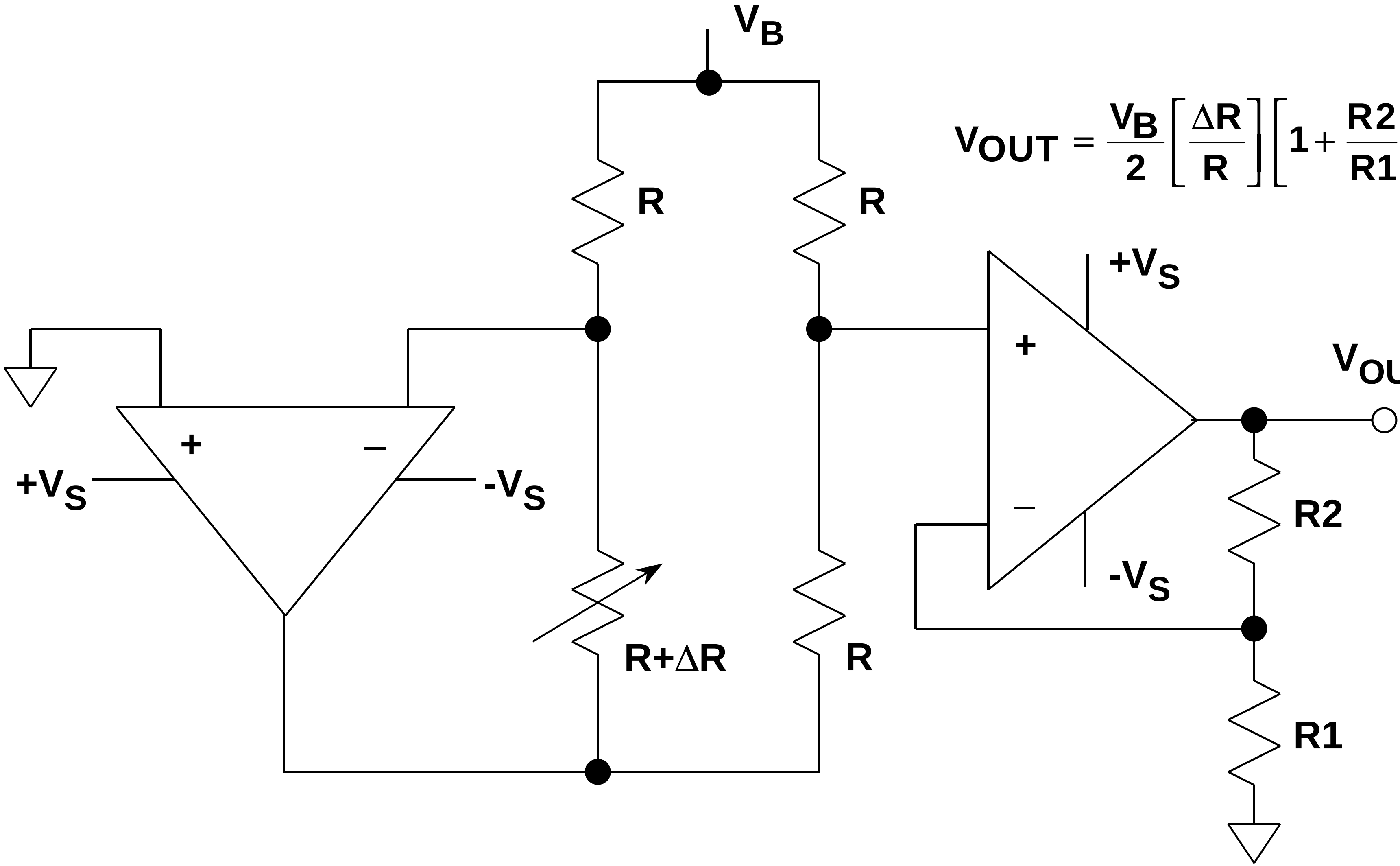
LINEARIZING A SINGLE-ELEMENT VARYING BRIDGE
METHOD 1



$$V_{OUT} = -V_B\left[\frac{\Delta R}{2R}\right]$$

LINEARIZING A SINGLE-ELEMENT VARYING BRIDGE
METHOD 2

$$V_{OUT} = \frac{V_B}{2}\left[\frac{\Delta R}{R}\right]\left[1+\frac{R2}{R1}\right]$$



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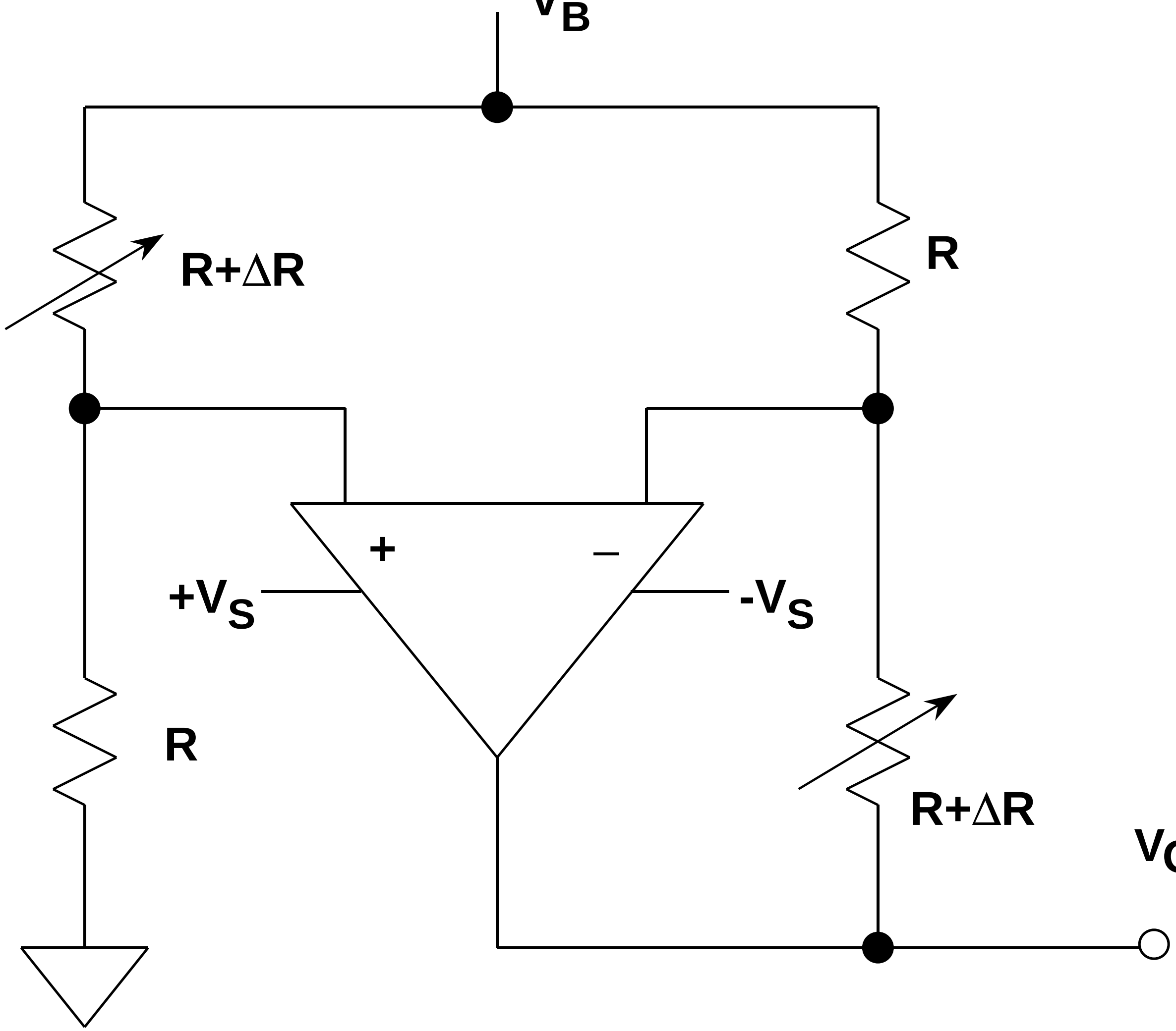
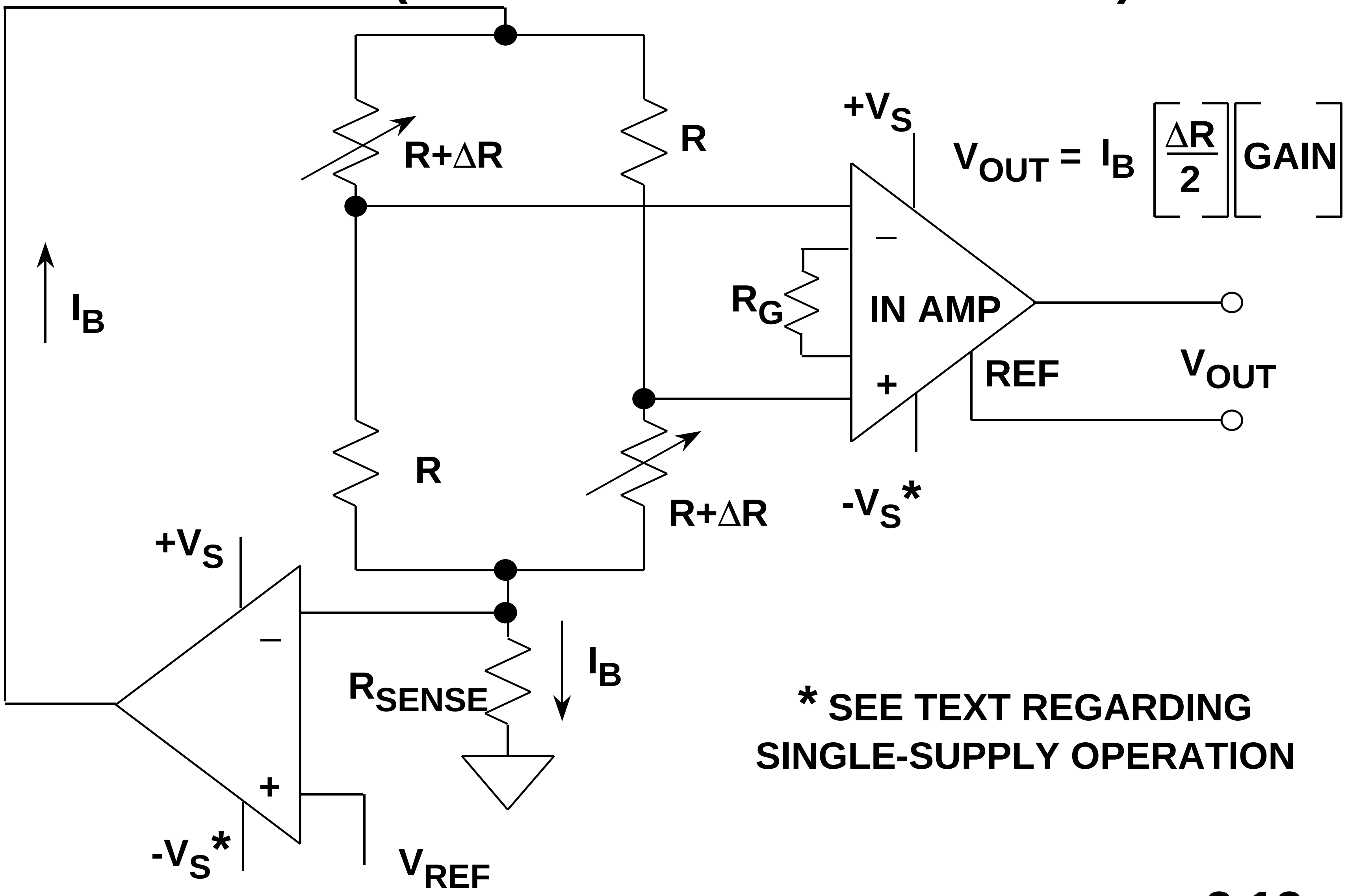
LINEARIZING A TWO-ELEMENT VARYING BRIDGE METHOD 1 (CONSTANT VOLTAGE DRIVE)



$$V_{OUT} = -V_B\left[\frac{\Delta R}{R}\right]$$

a

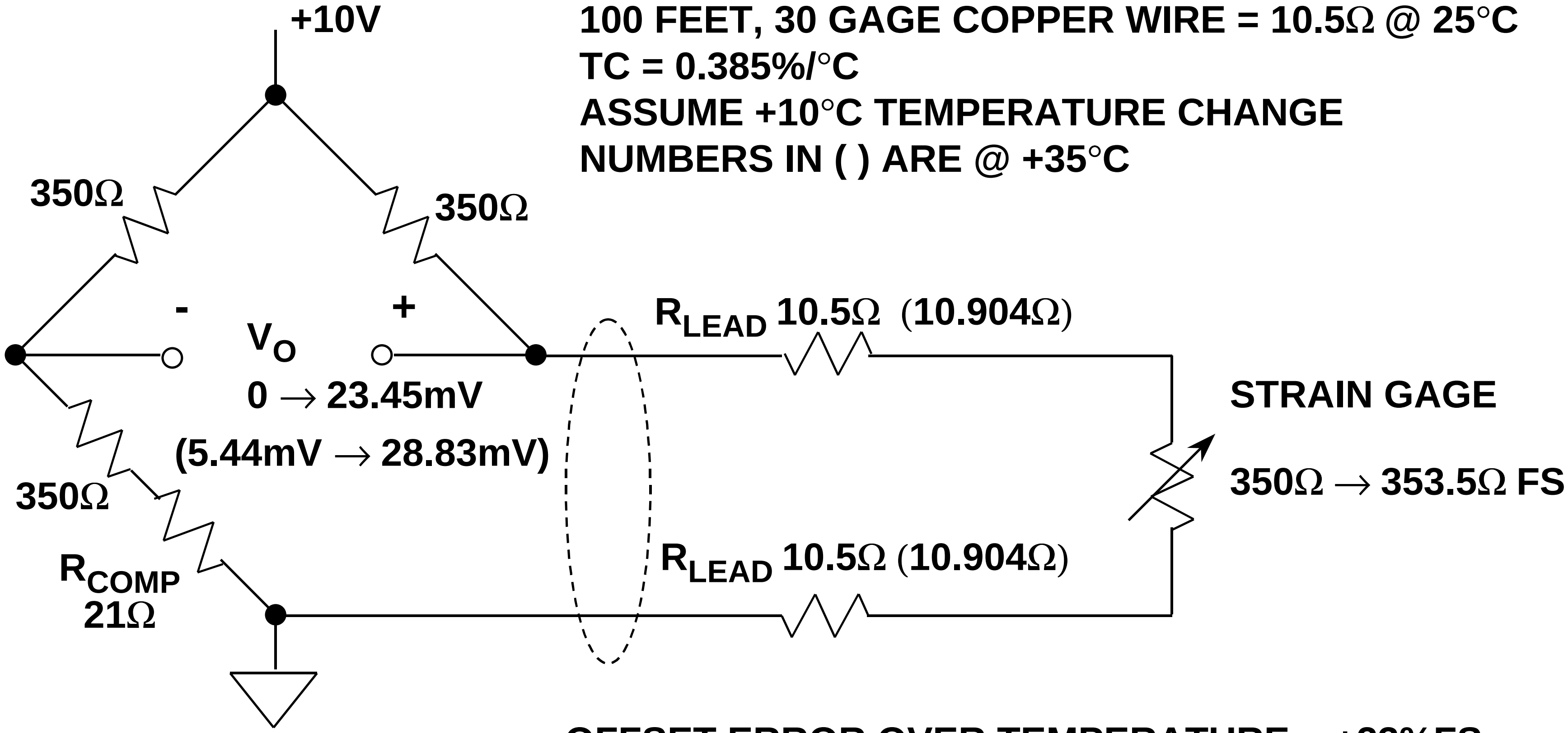
LINEARIZING A TWO-ELEMENT VARYING BRIDGE METHOD 2 (CONSTANT CURRENT DRIVE)



* SEE TEXT REGARDING SINGLE-SUPPLY OPERATION

ERRORS PRODUCED BY WIRING RESISTANCE FOR REMOTE RESISTIVE BRIDGE SENSOR

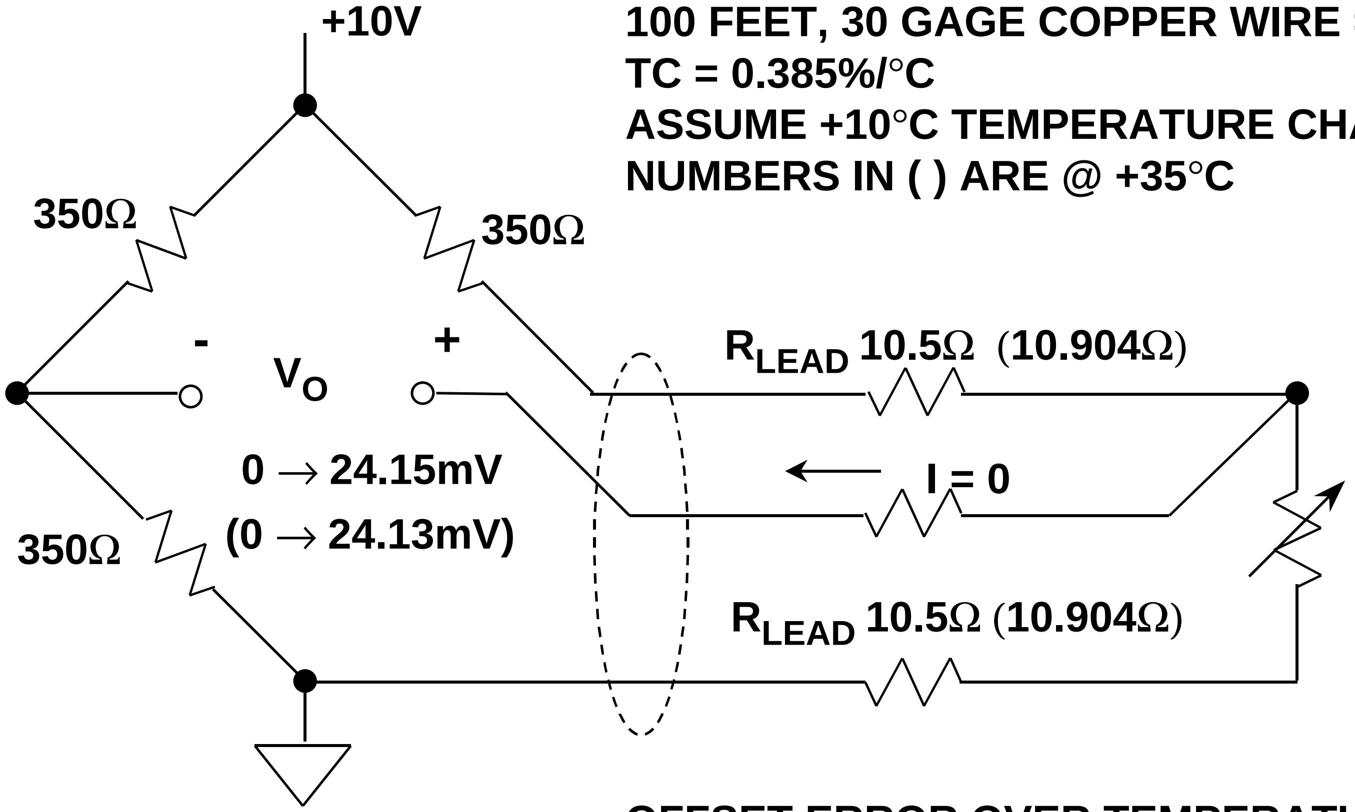
100 FEET, 30 GAGE COPPER WIRE = 10.5Ω @ 25°C
TC = 0.385%/°C
ASSUME +10°C TEMPERATURE CHANGE
NUMBERS IN ( ) ARE @ +35°C



OFFSET ERROR OVER TEMPERATURE = +23%FS

GAIN ERROR OVER TEMPERATURE = –0.26%FS

3-WIRE CONNECTION TO REMOTE BRIDGE ELEMENT (SINGLE-ELEMENT VARYING)

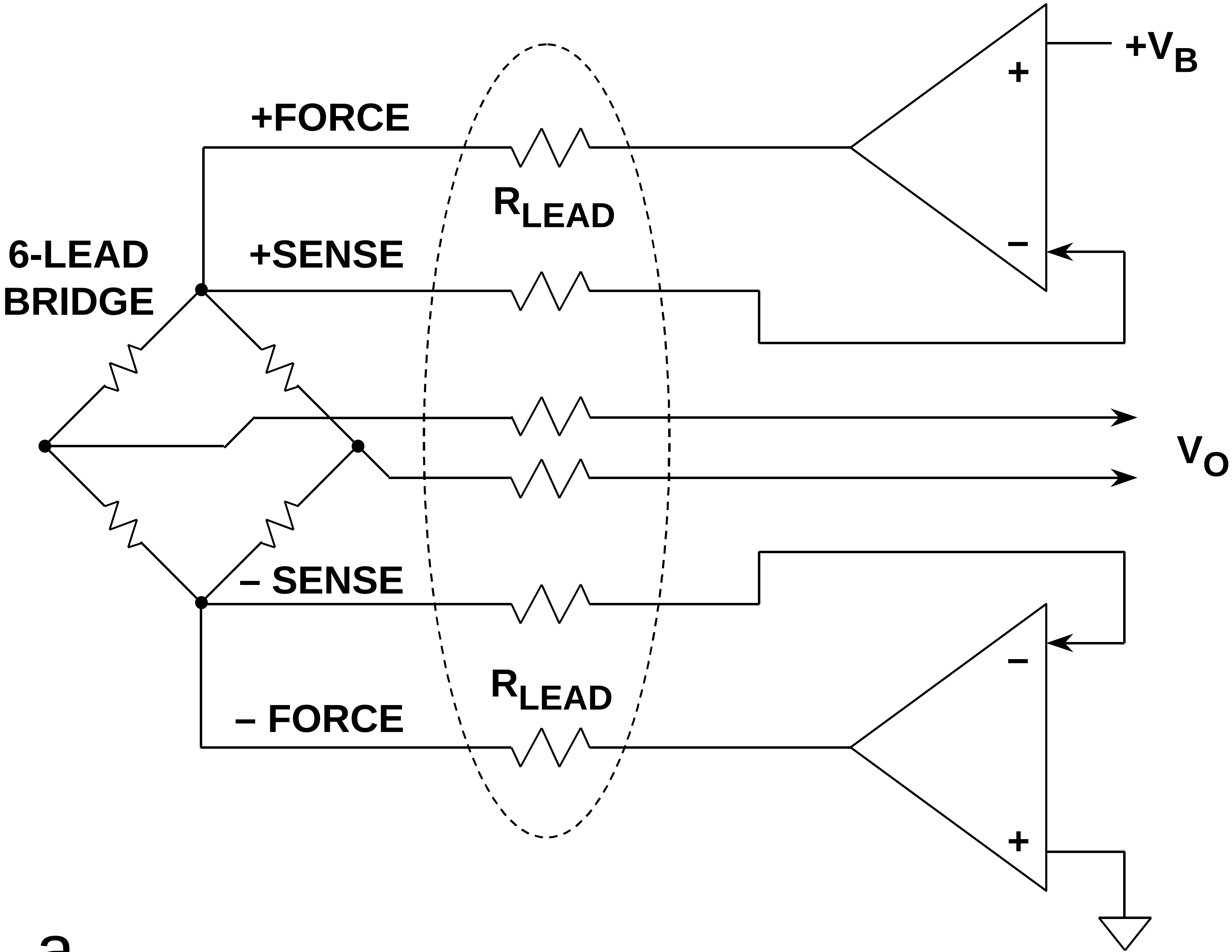


100 FEET, 30 GAGE COPPER WIRE = 10.5Ω @ 25°C
TC = 0.385%/°C
ASSUME +10°C TEMPERATURE CHANGE
NUMBERS IN ( ) ARE @ +35°C

OFFSET ERROR OVER TEMPERATURE = 0%FS

GAIN ERROR OVER TEMPERATURE = –0.08%FS

KELVIN (4-WIRE) SENSING MINIMIZES ERRORS DUE TO LEAD RESISTANCE



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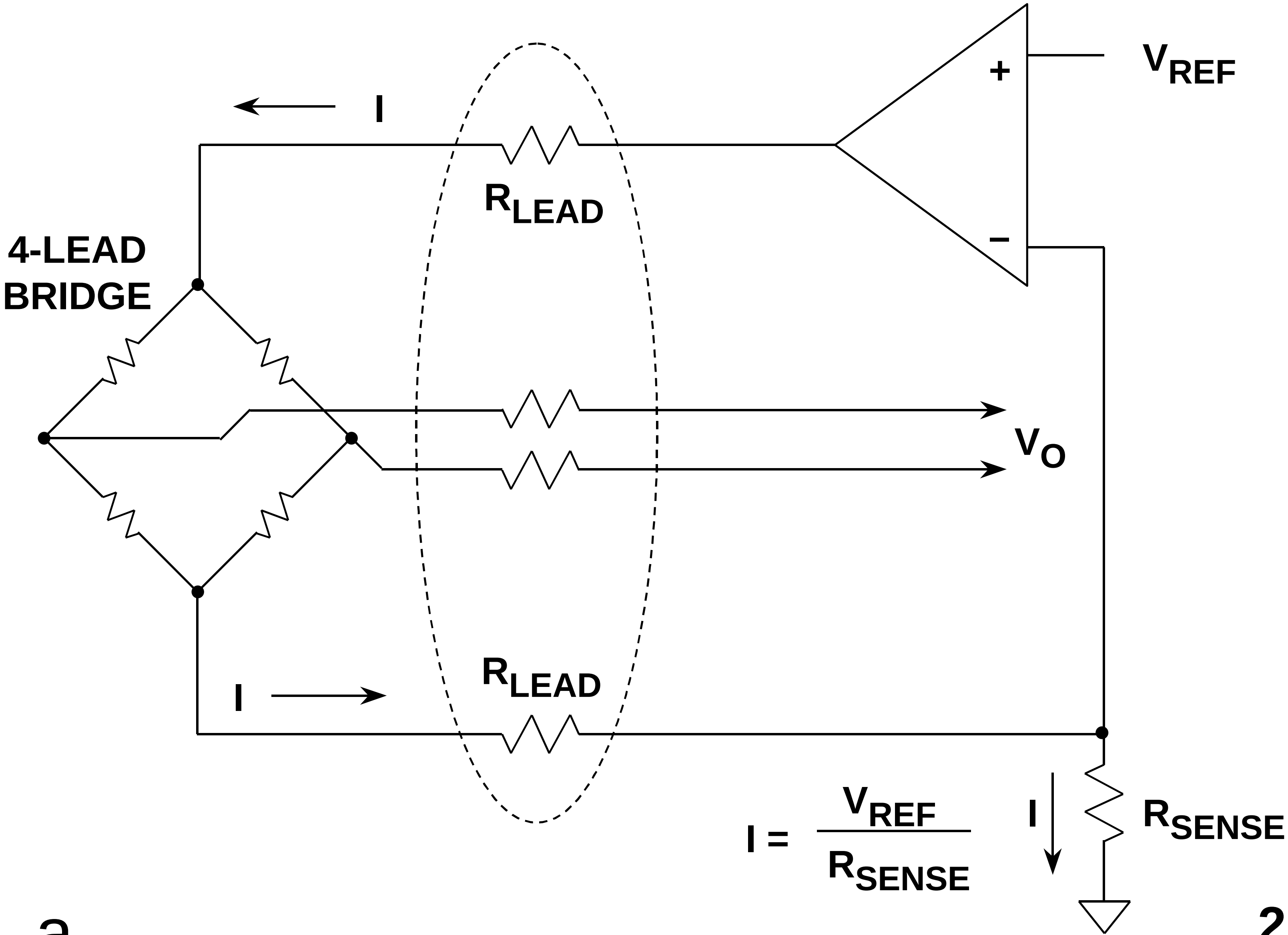
CONSTANT CURRENT EXCITATION MINIMIZES WIRING RESISTANCE ERRORS



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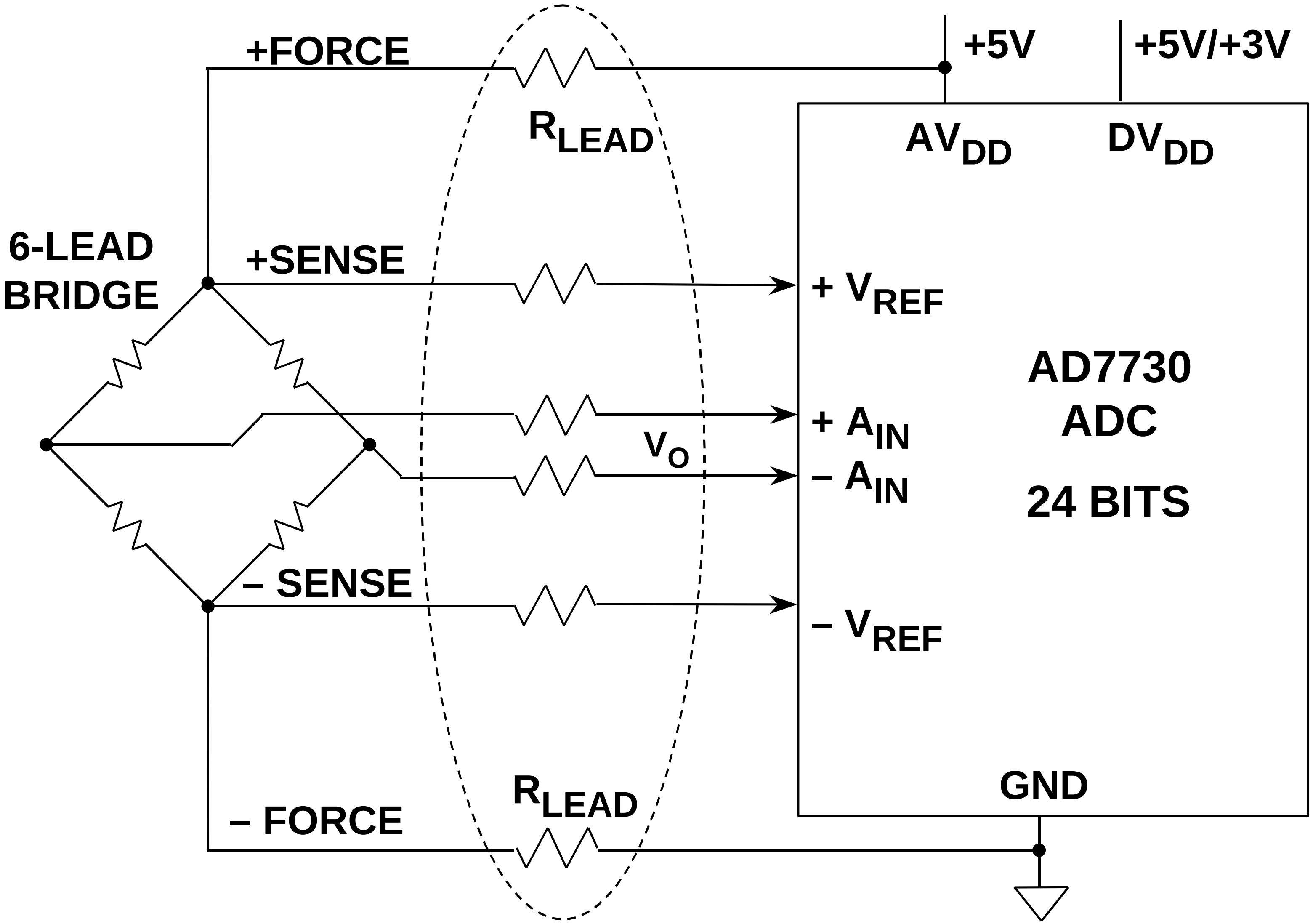
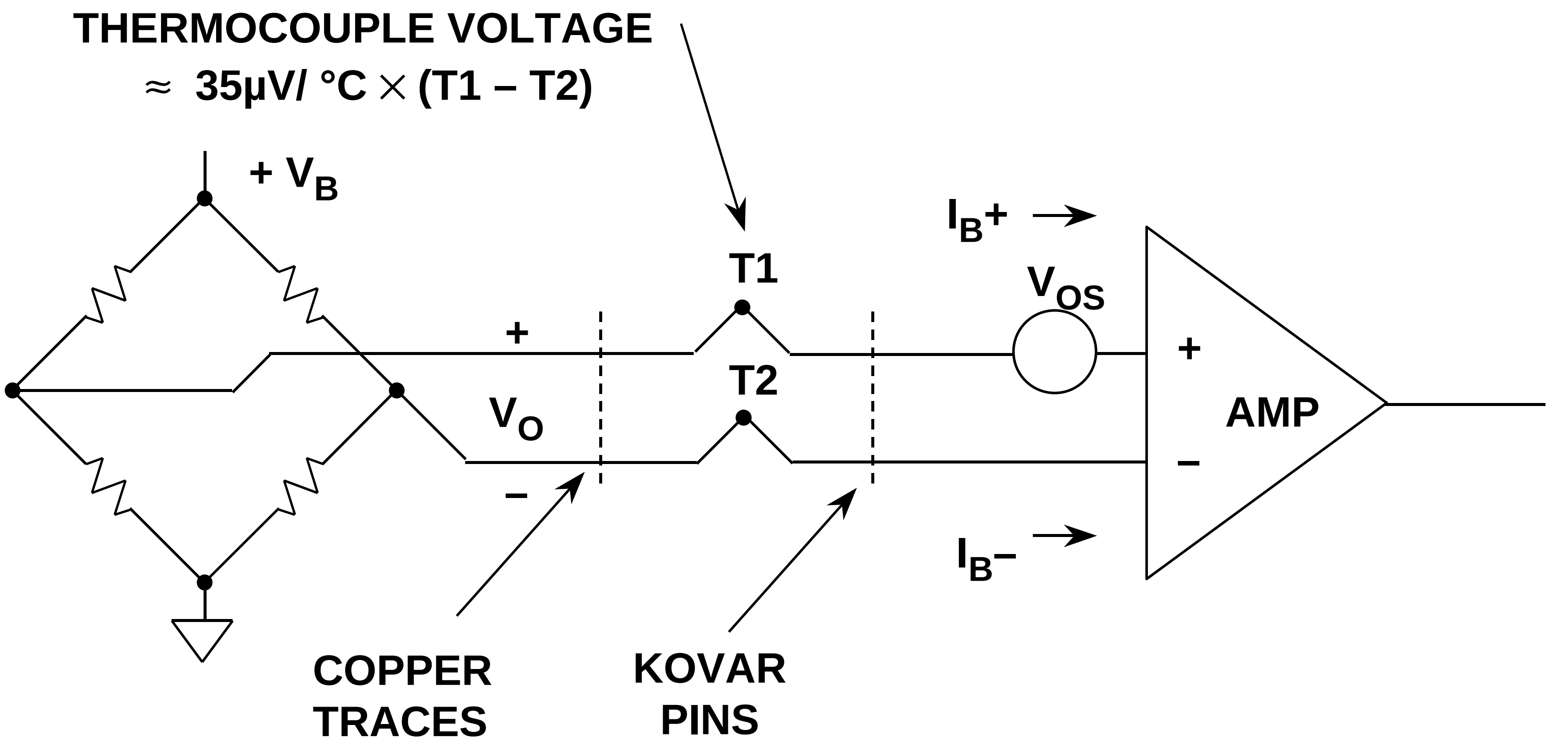
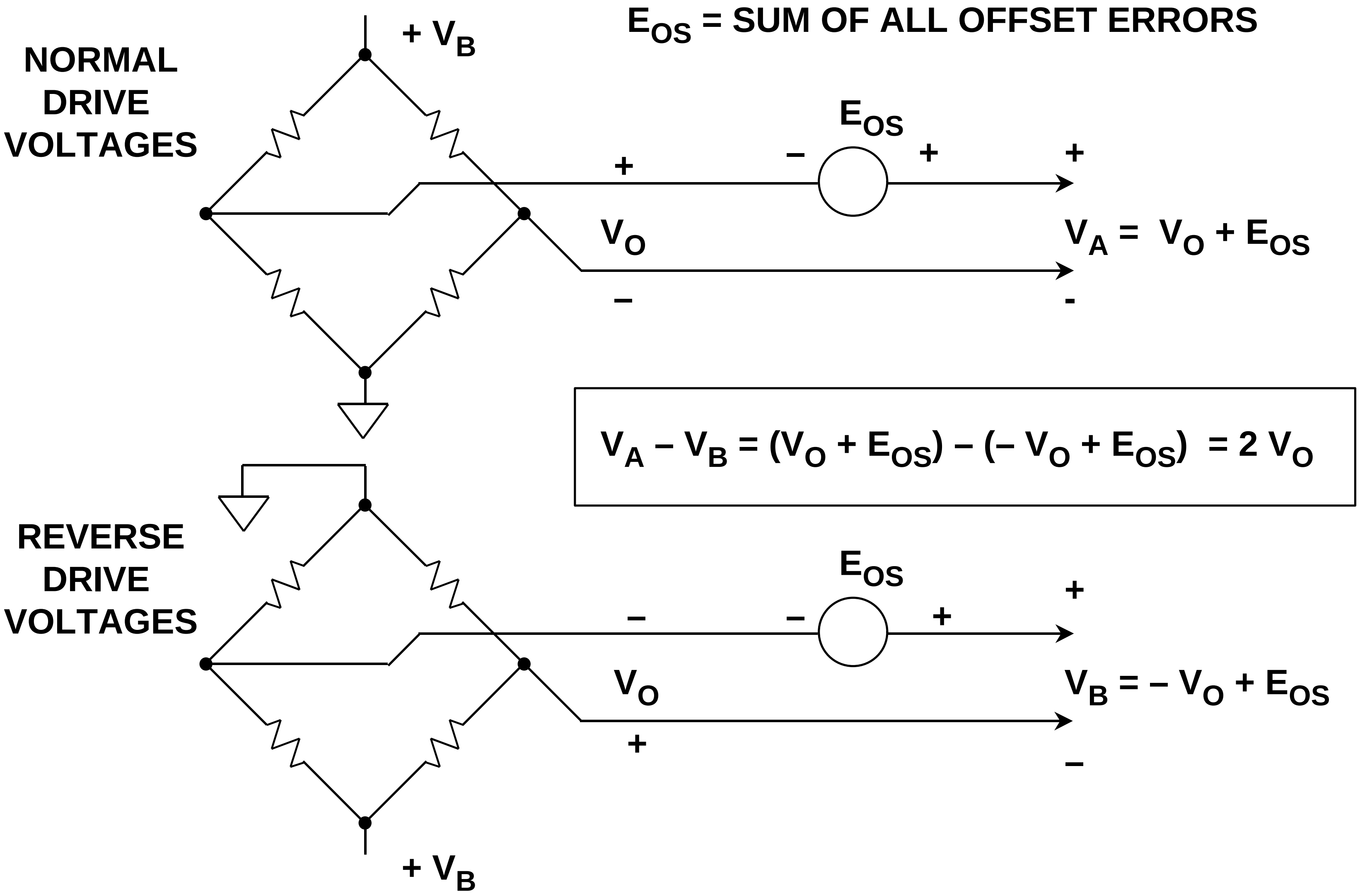
DRIVING REMOTE BRIDGE USING KELVIN (4-WIRE) SENSING AND RATIOMETRIC CONNECTION TO ADC



TYPICAL SOURCES OF OFFSET VOLTAGE

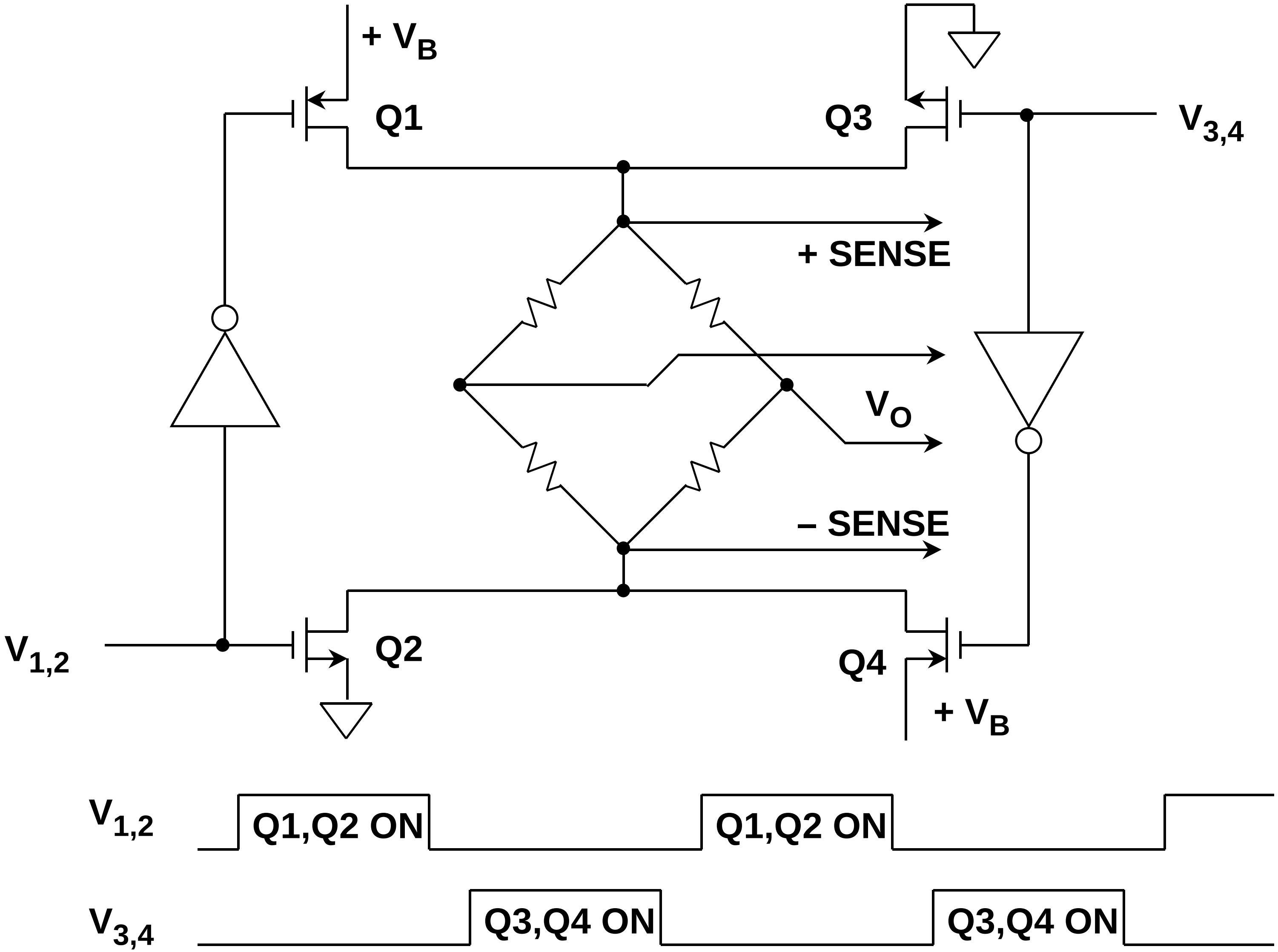


AC EXCITATION MINIMIZES OFFSET ERRORS



$$V_A - V_B = (V_O + E_{OS}) - (-V_O + E_{OS}) = 2\,V_O$$

SIMPLIFIED AC BRIDGE DRIVE CIRCUIT



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