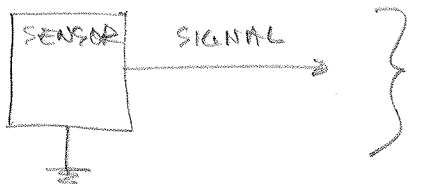
SUMMARY OF AMPLIFIERS, GROUNDING, SHIELDING

GROUNDING

SIGNALS MUST BE REFERENCED TO SOMETHING



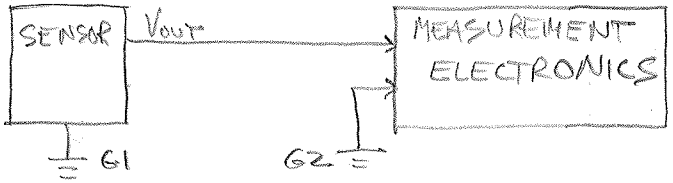
IDEALIZED. CAN BE MISSLEADING, APPEARS THAT WE ONLY NEED TO LOOK AT ONE SIGNAL LINE.

(FIG. 1)

NOTE: ALL SIGNAL SOURCES HAVE A MINIMUM OF TWO TERMINALS.

ALL RECEIVING CIRCUITS, I.E. AMPLIFIERS, HAVE TWO OR MORE TERMINALS.

ONE TERMINAL OFTEN IS STATED OR ASSUMED TO BE "GROUND"

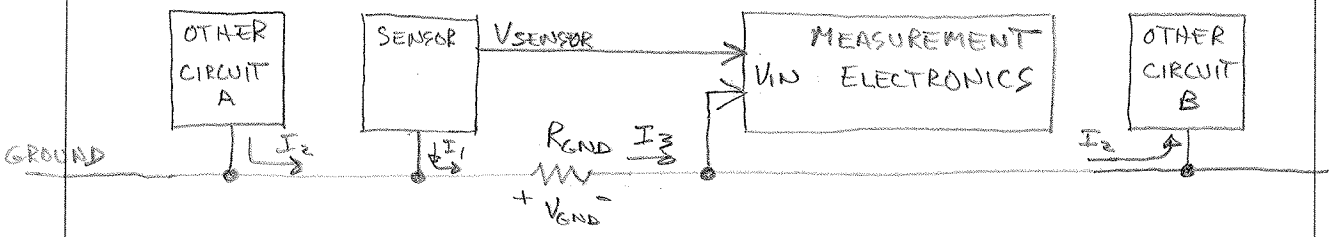


(FIG. 2)

CAUTION: AS SHOWN ABOVE, GROUND AT THE SENSOR IS ASSUMED TO BE AT THE SAME POTENTIAL AS GROUND AT THE MEASUREMENT ELECTRONICS. THIS EASILY CAN BE A FALSE ASSUMPTION.

NOTE WHAT CONNECTS GROUND 1 (G1) AND GROUND 2 (G2): AN UNDEFINED CONDUCTOR. THE MEASUREMENT ELECTRONICS WILL SENSE THE VOLTAGE BETWEEN ITS TWO INPUT TERMINALS.

POSSIBLE PROBLEM: NOISE INTRODUCED VIA COMMON SIGNAL PATH



(FIG. 3)

$I_3 = I_1 + I_2$. HOWEVER, ASSUME I_1 SMALL. $\therefore I_3 = I_2$

$V_{IN} = V_{SENSOR} + V_{GND}$

$\therefore V_{IN} = V_{SENSOR} + \underbrace{I_2 R_{GND}}_{V_{NOISE}}$

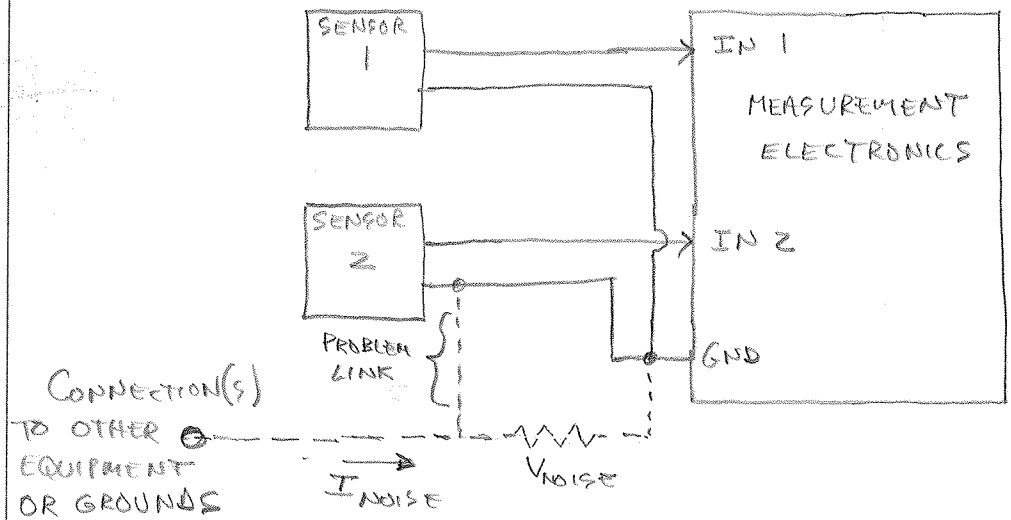
MORAL: GROUND CONNECTIONS MUST BE MADE CORRECTLY TO AVOID UNDESIRED ADDITION OF NOISE.

TWO TYPES OF AMPLIFIER INPUTS

SINGLE ENDED (UNBALALANCED)

- INPUT SIGNALS ARE REFERENCED TO SOME INTERNAL SYSTEM GROUND
- IF THERE ARE MULTIPLE INPUTS ALL INPUTS ARE REFERENCED TO A COMMON GROUND

EXAMPLE



(FIG. 4)

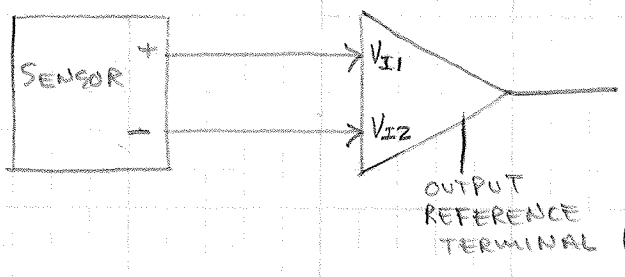
- NOISE VOLTAGE WILL COUPLE INTO THE AMPLIFIER IF THE CIRCUIT IS GROUNDED AT MORE THAN ONE POINT

(AMPLIFIER INPUTS CONTINUED)

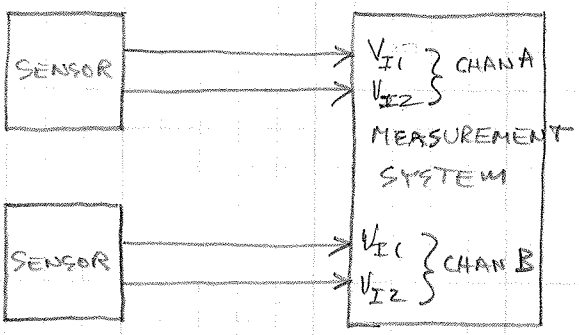
DIFFERENTIAL (BALANCED) AMPLIFIER INPUTS

- V_{IN} IS SENSED AS THE POTENTIAL BETWEEN THE TWO INPUTS, i.e. $(V_{I1} - V_{I2})$
- THE IMPEDANCE SEEN LOOKING INTO EACH INPUT IS IDENTICAL
- A VOLTAGE COMMON* TO BOTH INPUTS WILL CANCEL AND NOT EFFECT THE OUTPUT
  (* i.e. COMMON MODE VOLTAGE)

} IDEAL BEHAVIOR



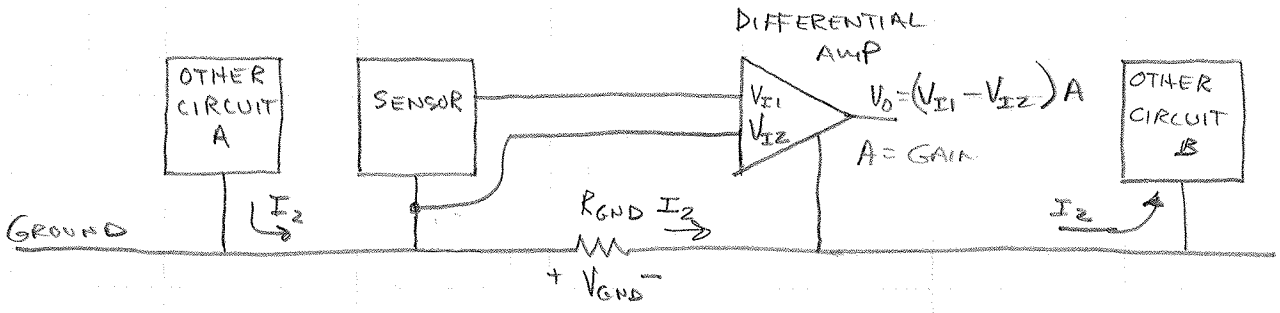
- IF DIFFERENTIAL INPUTS ARE USED FOR AN INSTRUMENTATION SYSTEM, THERE WILL BE TWICE AS MANY INPUT TERMINALS THAN A SINGLE ENDED SYSTEM



- PRACTICAL DIFFERENTIAL AMPLIFIERS HAVE A LIMITED COMMON MODE VOLTAGE RANGE
- REAL DIFFERENTIAL AMPLIFIERS DON'T PERFECTLY REJECT COMMON MODE VOLTAGE.
- COMMON MODE REJECTION RATIO (CMRR) IS A SPECIFICATION QUANTIFYING HOW WELL AN AMPLIFIER REJECTS COMMON MODE VOLTAGE. FOR EXAMPLE, IF CMRR = 60 DB, A COMMON MODE VOLTAGE WILL PRODUCE AN AMPLIFIER OUTPUT 0.001 OF WHAT IT WOULD

13-782 500 SHEETS, FILLER 5 SQUARE
42-381 50 SHEETS EYE-EASE® 5 SQUARE
42-382 100 SHEETS EYE-EASE® 5 SQUARE
42-389 200 SHEETS EYE-EASE® 5 SQUARE
42-392 100 RECYCLED WHITE 5 SQUARE
42-399 200 RECYCLED WHITE 5 SQUARE
Made in U.S.A.
National® Brand

REDRAWING FIGURE 3:



(FIG. 4)

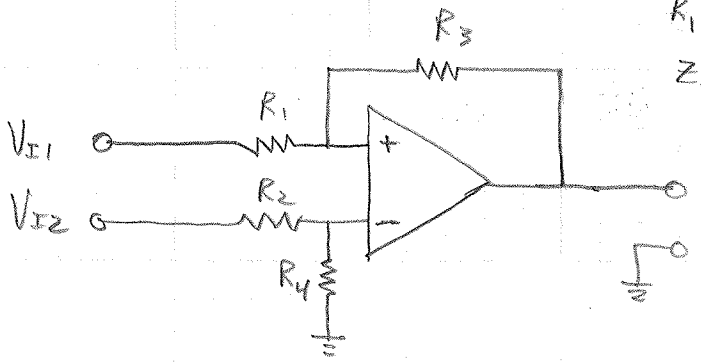
- USING A DIFFERENTIAL AMPLIFIER, CONNECTIONS CAN BE MADE DIRECTLY BETWEEN AMP INPUT AND SENSOR OUTPUT. THE SENSOR OUTPUT CAN STILL BE REFERENCED (i.e. CONNECTED) TO A SYSTEM GROUND. BUT NOW V_{GND} CAUSED BY I_2 WILL BE SEEN AS A COMMON MODE VOLTAGE AND WILL BE REJECTED (TO THE EXTENT SPECIFIED BY CMRR)

- A DIFFERENTIAL AMPLIFIER WITH THESE CHARACTERISTICS, AMONG OTHERS, IS CALLED AN INSTRUMENTATION AMPLIFIER
  - GOOD COMMON MODE REJECTION
  - MATCHED IMPEDANCE FOR INPUTS V_{I1} & V_{I2}.
  - HIGH IMPEDANCE AT EACH INPUT
  - GAIN TYPICALLY SELECTABLE FROM 1 TO 1000

- A DIFFERENTIAL AMPLIFIER CAN BE CONSTRUCTED USING AN OP AMP, BUT THE INPUT IMPEDANCE IS FAIRLY LOW

$R_1 = R_2$ & $R_3 = R_4$

$Z_{IN} = 2R_1$



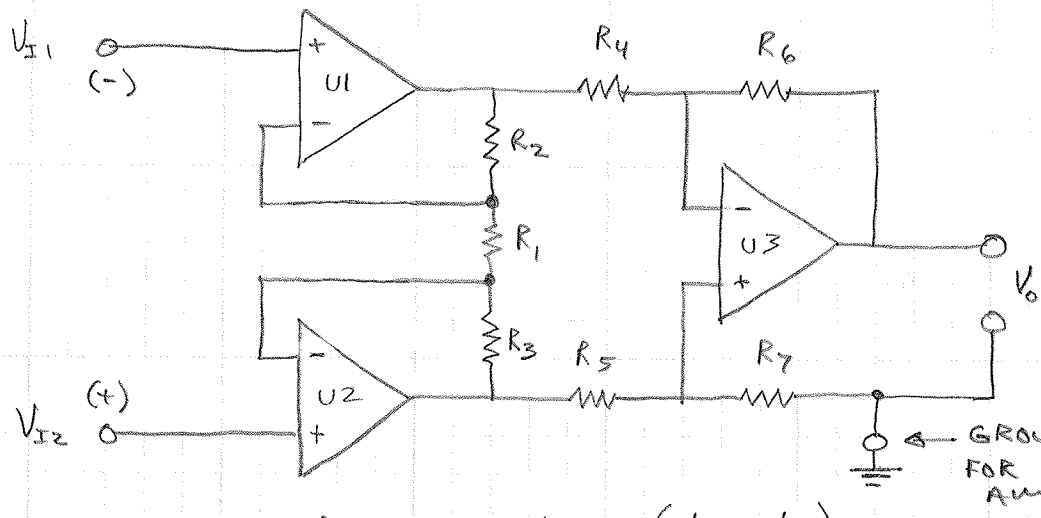
$$V_O = \frac{R_3}{R_1}(V_{I1} - V_{I2})$$

(FIG 5)

RESISTOR MATCHING MUST BE PRECISE TO ACHIEVE HIGH CMRR

13-782 500 SHEETS FILLER 5 SQUARE
42-381 500 SHEETS EYE-EASE® 5 SQUARE
42-382 100 SHEETS EYE-EASE® 5 SQUARE
42-388 200 SHEETS EYE-EASE® 5 SQUARE
42-392 100 RECYCLED WHITE 5 SQUARE
42-399 200 RECYCLED WHITE 5 SQUARE
Made in U.S.A.
National® Brand

- A TRUE INSTRUMENTATION AMPLIFIER HAS A TOPOLOGY SIMILIER TO THIS:



(FIG 6)

ASSUMPTIONS: $\begin{cases} R_2 = R_3 \\ R_4 = R_5 \\ R_6 = R_7 \end{cases}$ THEN: $V_o = G\,(V_{I1} - V_{I2})$

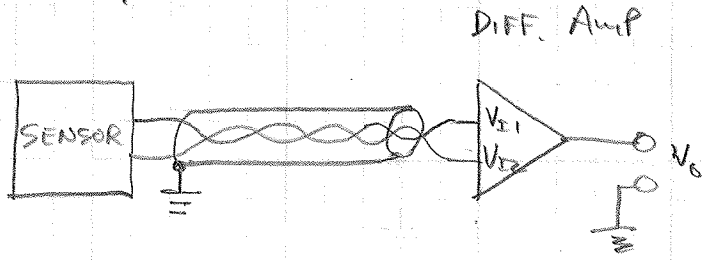
$$G = \left(1 + \frac{2R_2}{R_1}\right)\left(\frac{R_6}{R_4}\right)$$

- AMPLIFIER INPUT IMPEDANCE IS DETERMINED BY THE INPUT CHARACTERISTICS OF U1 & U2.

REDUCING NOISE PICKUP IN WIRING

1— USE TWISTED PAIR WIRE BETWEEN SENSOR AND AMP

2— IF JUST TWISTED PAIR WIRE DOESN'T ADEQUATELY REJECT THE NOISE THEN USE TWISTED PAIR WITH A SHIELD AROUND IT. CONNECT THE SHIELD AT ONLY ONE END.



(FIG 7)

NOISE PICKED UP FROM THE ENVIRONMENT VIA ELECTRO-MAGNETIC COUPLING WILL TEND TO FLOW ON THE SHIELD TO GROUND AND THE TWISTED PAIR OF SIGNAL WIRES WON'T HAVE NOISE COUPLED TO THEM.

13-782 500 SHEETS, FILLER 5 SQUARE
42-381 50 SHEETS EYE-EASE® 5 SQUARE
42-382 100 SHEETS EYE-EASE® 5 SQUARE
42-389 200 SHEETS EYE-EASE® 5 SQUARE
42-392 100 RECYCLED WHITE 5 SQUARE
42-399 200 RECYCLED WHITE 5 SQUARE
Made in U.S.A.
National® Brand