INA148 & INA149 Transfer function math

Texas Instruments

General derivation of inverting T network

Inverting T network amp

$$\frac{0-V_{in}}{R_{in}}+\frac{0-V_x}{R_f}=0$$ Equ 1

$$V_x=\frac{-(R_f \cdot V_{in})}{R_{in}}$$ Solve Equ 1 for Vx

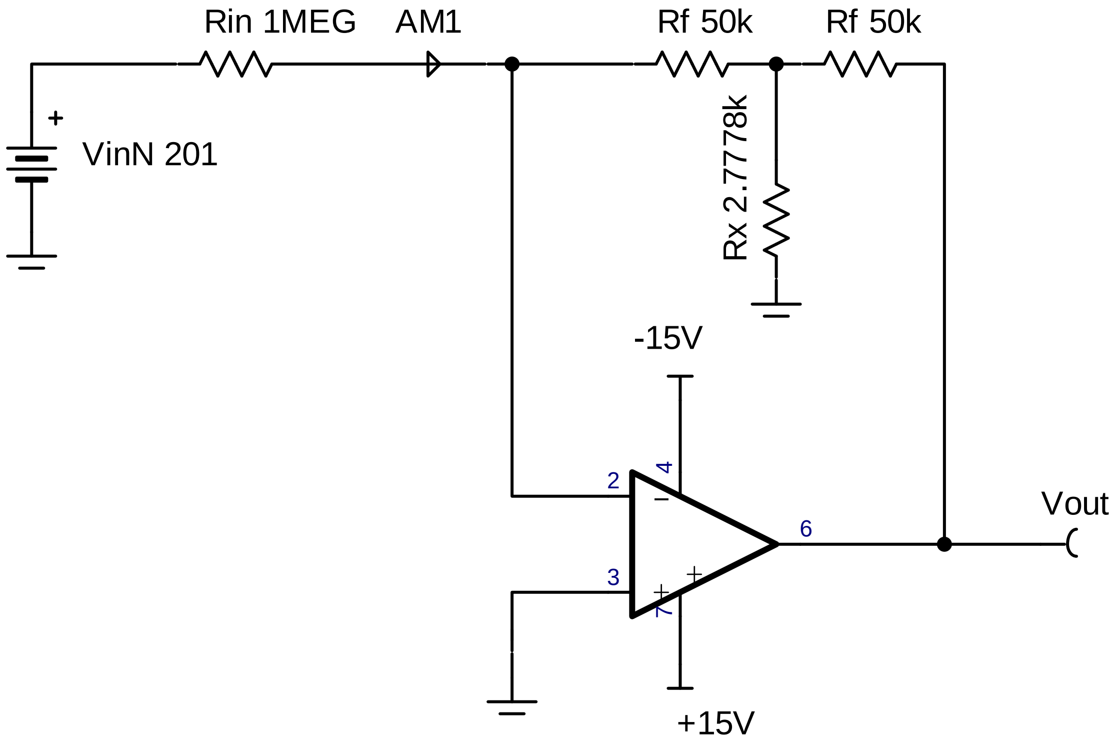
$$\frac{V_x-0}{R_f}+\frac{V_x}{R_x}+\frac{V_x-V_{out}}{R_f}=0$$ Equ 2

$$-\frac{V_{out}}{R_f}-\left(\frac{2 \cdot V_{in}}{R_{in}}+\frac{R_f \cdot V_{in}}{R_{in} \cdot R_x}\right)=0$$ Substitute Equ 1 into Equ 2

$$G_{invT}=\frac{V_{out}}{V_{in}}=\frac{-R_f}{R_{in}} \cdot \left(2+\frac{R_f}{R_x}\right)$$ Solve for Vout/Vin and simplify

$$V_{out}=G_{invT} \cdot V_{in}=\frac{-R_f}{R_{in}} \cdot \left(2+\frac{R_f}{R_x}\right) V_{in}$$ General Relationship

$$V_{out}=\frac{-50\ k\Omega}{1\ M\Omega}\left(\left(2+\frac{50\ k\Omega}{2.7778\ k\Omega}\right)\right)=-V_{in}$$ Equ 3: INA148 example



General derivation of non-inverting t-network

$$\frac{V_{in}-0}{R_{in}}+\frac{V_{in}-V_x}{R_f}=0$$ Equ 4

$$V_x=\frac{(R_{in}+R_f)\cdot V_{in}}{R_{in}}$$ Solve Equ 5 for Vx

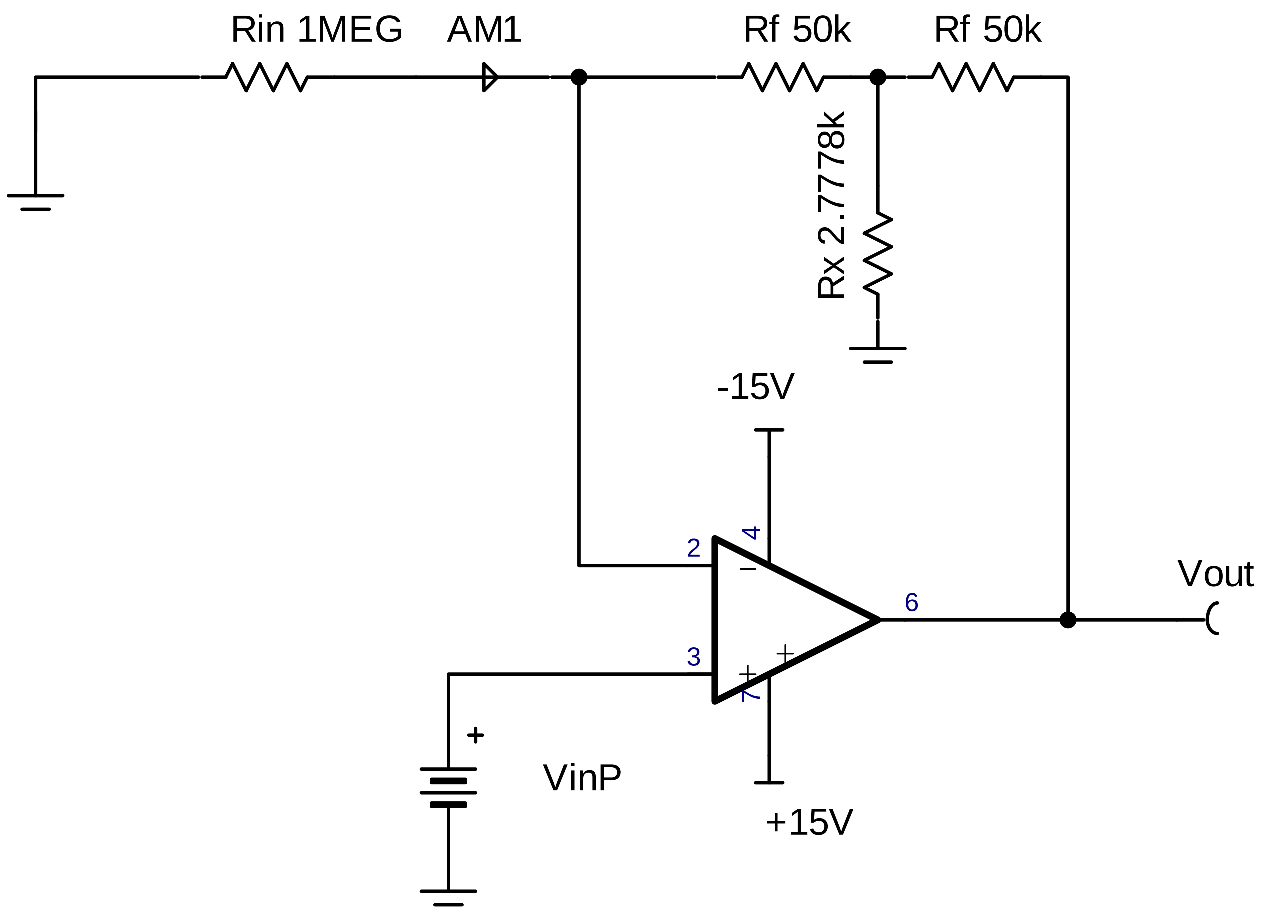
$$\frac{V_x-V_{in}}{R_f}+\frac{V_x}{R_x}+\frac{V_x-V_{out}}{R_f}=0$$ Equ 5

$$-\frac{V_{out}}{R_f}+\frac{V_{in}}{R_f}+\frac{2\cdot V_{in}}{R_{in}}+\frac{V_{in}}{R_x}+\frac{R_f\cdot V_{in}}{R_{in}\cdot R_x}=0$$ Substitute 4 into 5

$$G_{nonT}=\left(1+\frac{R_f}{R_x}\right)+\frac{R_f}{R_{in}}\left(2+\frac{R_f}{R_x}\right)$$ Solve for gain and simplify

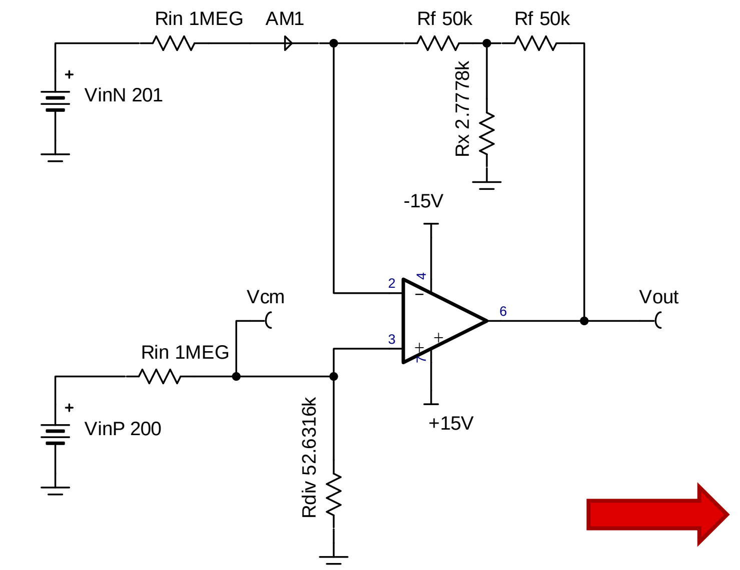
$$G_{nonT}:=\left(1+\frac{50\ k\Omega}{2.7778\ k\Omega}\right)+\frac{50\ k\Omega}{1\ M\Omega}\left(2+\frac{50\ k\Omega}{2.7778\ k\Omega}\right)=20$$

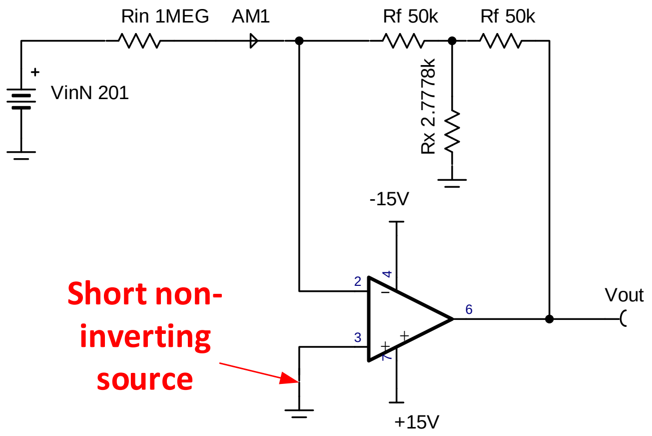
$$V_{out}=20\ V_{in}$$ For INA148 example



TEXAS INSTRUMENTS

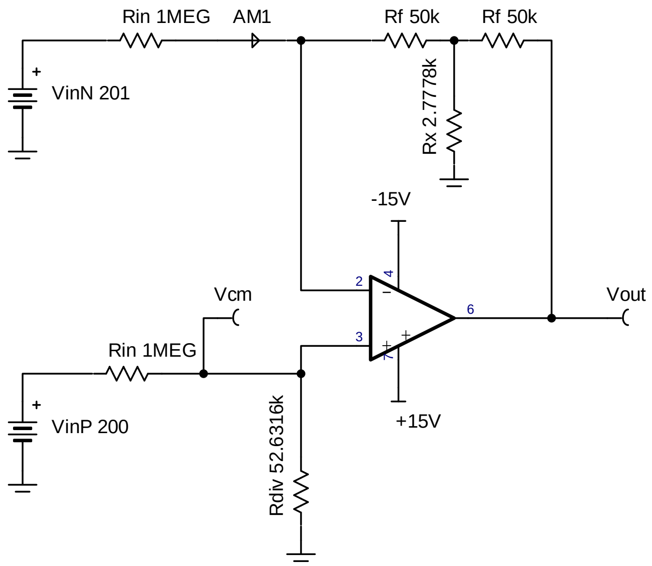
INA148 Gain – use superposition

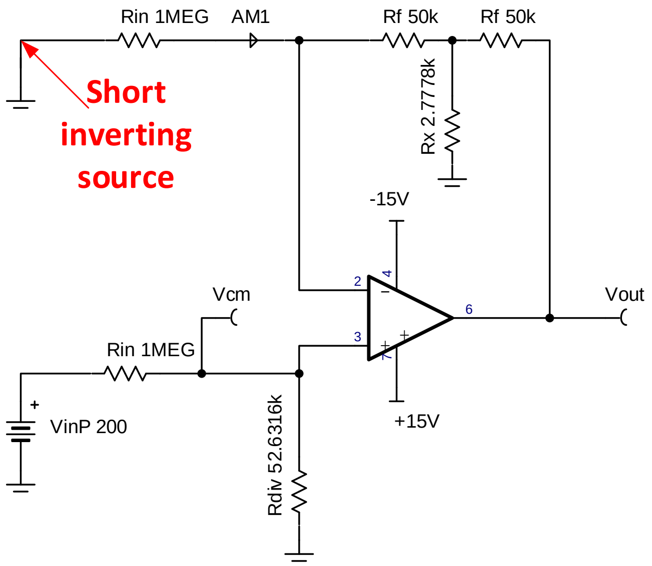




$$V_{outN} = -V_{inN}$$

Equ 3: Noninverting with voltage divider for INA148 example





$$V_{outP} = G_{nonT} \cdot \left(V_{inP} \cdot \frac{R_{div}}{R_{div} + R_{in}} \right) = 20$$ with voltage divider

$$V_{outP} = G_{nonT} \cdot \left(\frac{R_{div}}{R_{div} + R_{in}} \right) \cdot V_{inP} = 20 \cdot \left(\frac{1}{20} \right) \cdot V_{inP} = V_{inP}$$

$$V_{outP} = V_{inP}$$

Equ 6: Noninverting with voltage divider

$$V_{outN} + V_{outP} = V_{inP} - V_{inN}$$

Final result: add equation 3 and 6 from superposition

$$\frac{V_{outN} + V_{outP}}{V_{inP} - V_{inN}} = 1$$

Differential gain = 1

INA149 derivation

$$\frac{V_{cm}-V_{inN}}{R_{in}}+\frac{V_{cm}}{R_x}+\frac{V_{cm}-V_{out}}{R_f}=0$$

Equ 1: node at Vx

$$R_{div}=\frac{R_f \cdot R_x}{R_f+R_x}$$

Equ 2: let Rdiv = Rf || Rx

$$V_{cm}=\frac{R_{div}}{R_{div}+R_{in}} \cdot V_{inP}$$

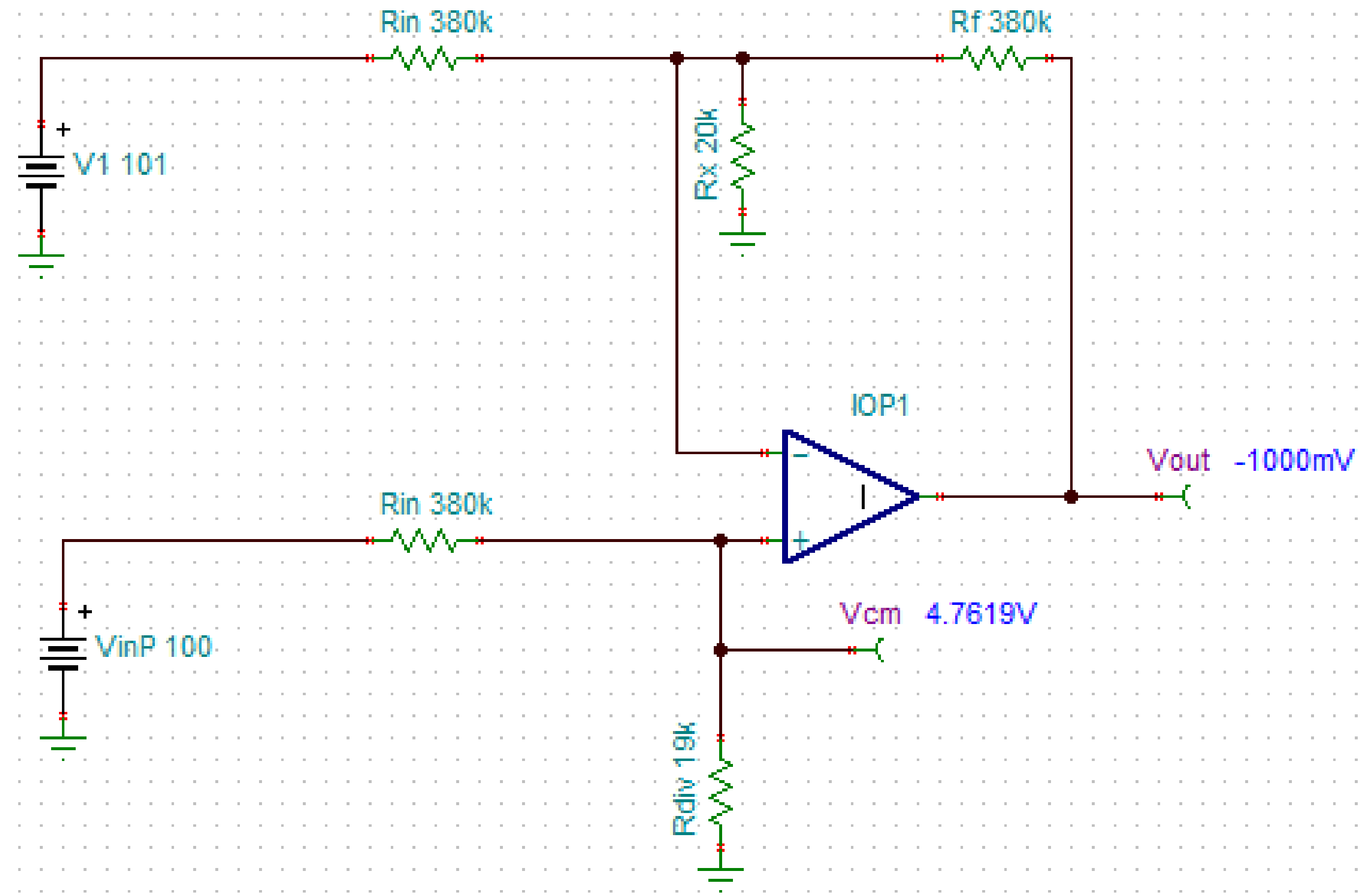
Equ 3: Voltage divider

$$V_{cm}=\frac{R_f \cdot R_x \cdot V_{inP}}{(R_{in}+R_f) \cdot R_x+R_f \cdot R_{in}}$$

Equ 4: substitute 2 into 3

$$V_{out}=\frac{R_f}{R_{in}} \cdot (V_{inP}-V_{inN})$$

Equ 5: substitute 4 into 1



Common mode applied to the amplifiers