Summing Scaling and Averaging Amplifiers.

Inverting configuration.

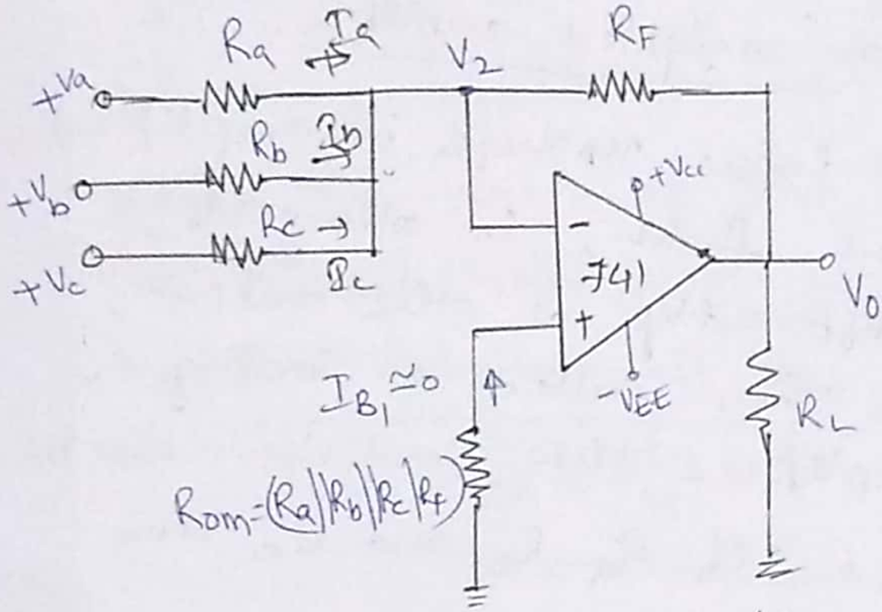

Fig: 1

Fig:1 shows the inverting configuration with three inputs V_a, V_b and V_c. Depending on the relationship between the feed back resistor R_F and the i/p resistors R_a, R_b and R_c, the circuit can be used as a summing amplifier, a scaling amplifier, or an averaging amplifier.

The out put voltage V_o can be obtained from KCL equation at node V_2

$$I_a + I_b + I_c = I_B + I_F$$

$$\frac{V_a}{R_a} + \frac{V_b}{R_b} + \frac{V_c}{R_c} = -\frac{V_o}{R_F}$$

$\because R_i$ and A of the op-amp idealy infinite $I_B = 0$ and $V_1 = V_2 = 0$

$$V_o = -\left[\frac{R_F}{R_a} V_a + \frac{R_F}{R_a} V_b + \frac{R_F}{R_c} V_c\right] \quad \text{---} \ ①$$

(a) Scaling or weighted amplifier.

If each input voltage is amplified by a different factor, in otherwords, weighted differently at the output, the ckt is then called a Scaling or weighted amplifier. This condition can be accomplished if R_a, R_b, and R_c are different in value.

Thus the output voltage of the ~~scaling~~ Scaling amplifier is

$$V_o = -\left[\frac{R_F}{R_a} V_a + \frac{R_F}{R_b} V_b + \frac{R_F}{R_c} V_c\right]$$

$$\frac{R_F}{R_a} \neq \frac{R_F}{R_b} \neq \frac{R_F}{R_c}$$

(B) Summing amplifier.

If in the ckt of Fig. 1, $R_a = R_b = R_c = R$ then equation

$$V_o = -\frac{R_F}{R}(V_a + V_b + V_c)$$

This means that the output voltage

is equal to the negative sum off all the input times the gain of the circuit $\frac{R_F}{R_1}$. hence the circuit is called a summing amplifier.

when the gain of the circuit is 1 the output voltage is equal to the negative sum of all I/p voltages, Thus

$$\boxed{V_o = -(V_a + V_b + V_c)} \quad \text{--- (2)}$$

(c) <u>Average circuit</u>.

The circuit show in fig 1 can be used as an averaging circuit, in which the output voltage is equal to the average of all the I/p voltages.

This is accomplished by using all input resistors of equal value, $R_a = R_b = R_c = R$

In addition, the gain by which each input is amplified must be equal to 1 over the number of inputs. i-e

$$\frac{R_F}{R} = \frac{1}{n}.$$

where 'n' is the number of I/ps.

Thus, if there are three I/ps,

$$\frac{R_F}{R} = \frac{1}{3}$$

then $V_o = -\left[\frac{V_a + V_b + V_c}{3}\right]$ —— (5)

The offset minimizing resistor R_{om} is used to minimize the effect of Input bais currents on the output offset voltage.

Non inverting configuration (Averaging & Summing amplifier)

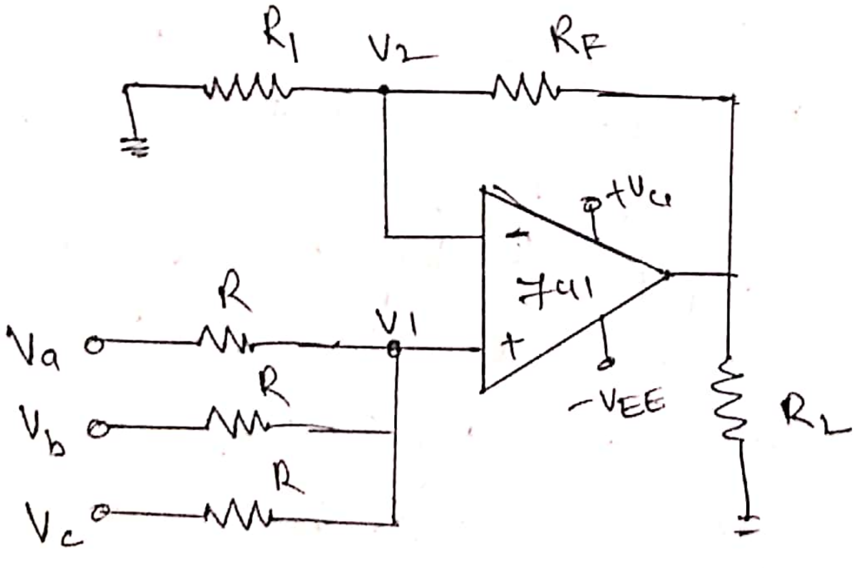

Fig: 2

If the input voltage sources and resistors are connected to the noninverting terminal as shown in Fig: 2, the ckt canbe used either as a summing or averging amplifier. Through selection of appropriate values of resistors that is R_1 and R_F.

To verify the functions of the circuit, the expression for the output voltage must be obtained.
The I/p resistance of the non inverting amplifier is very large, using superposition theorem, the voltage V_1 at the non inverting terminal is

$$V_1 = \frac{R/2}{R+R/2} V_a + \frac{R/2}{R+R/2} V_b + \frac{R/2}{R+R/2} V_c$$

or $$V_1 = \frac{V_a}{3} + \frac{V_b}{3} + \frac{V_c}{3}$$

$$V_1 = \frac{V_a+V_b+V_c}{3}.$$

The output voltage $V_o = \left(1+\frac{R_F}{R_1}\right) V_1$

$$V_o = \left(1+\frac{R_F}{R_1}\right)\left(\frac{V_a+V_b+V_c}{3}\right) \quad \text{—— (4)}$$

(a) <u>Averaging amplifier</u>

Eqn (4) shows that the output voltage is equal to the average of all I/p voltages times the gain of the circuit $(1+R_F/R_1)$.

hence the name averaging amplif.

Depending on the application requirement the gain $\left(1+\frac{R_F}{R_1}\right)$ can be set to a specific value.

If the gain is 1, the output voltage will be equal to the average of all I/p voltages.

(b) Summing amplifier.

In equation (4), if the gain $\left(1+\frac{R_F}{R_1}\right)$ is equal to the number of inputs, the output voltage becomes equal to the sum of all I/p voltages.

i.e if $\left(1+\frac{R_F}{R_1}\right)=3$.

$$\boxed{V_o = V_a + V_b + V_c}$$

Hence it is called Non inverting Summing amplifier.

Instrumentation Amplifier

(1)

* In many industrial and consumer application the measurement and control of physical conditions are very important.
* For example, measurements of temp and humidity inside a dairy or meat plant permit the operator to make necessary adjustments to maintain product quality.
* Similarly, precise temperature control of a plastic furnace is needed to produce a particular type of plastic.
* A transducer is used at the measuring site to obtain the required information easily and safely.
* The transducer is a device that converts one form of energy into another.
* For example, a strain gage when subjected to pressure or force (physical energy) undergoes a change in its

resistance (electrical energy).

* An instrumentation system is used to measure the output signal produced by a transducer and often to control the physical signal producing it.

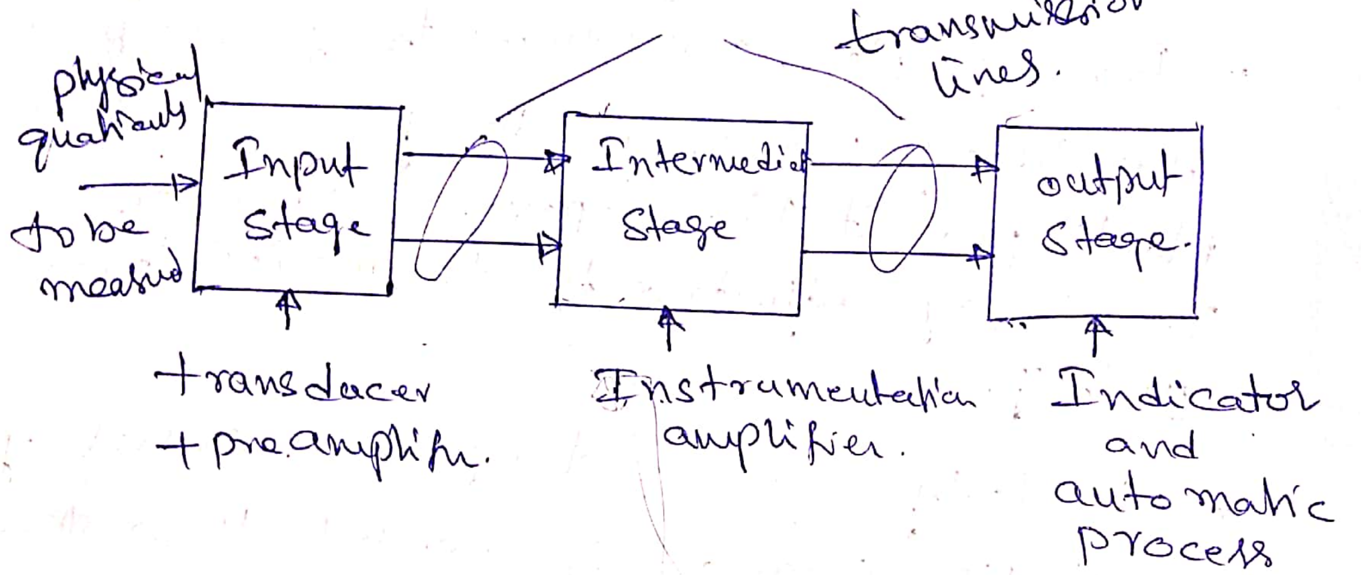

Fig: Block diagram of an Instrumentation System.

* The input stage is composed composed of a preamplifier and some sort of transducer, depending on the physical quantity to be measured.

* The output stage may use devices such a meters, oscilloscopes, charts, or magnetic recoders.

* The connecting lines between the blocks represents transmission lines, used especially when the transducer is at a remote test site monitoring hazardous conditions such as high tempuratures or liquid levels of flamable chemicals. These transmission lines permit signal transfer from unit to unit. The length of the transmission lines depends primarily on the physical quatities to be monitored and on system requirments.

* The signal source of the instrumentation amplifier is the output of the transducer. Although some of the transducers produce outputs with sufficient strength to permit their use directly many do not.

To amplify the low-level output signal of the transducer so that it can drive the indicator or display is the major function of the instrumentation amplifier. In sort, the instrumentation amplifier is intended for precise, low-level signal amplification where low noise, low thermal and time drifts, high input resistance, high common mode rejection ratio, and high slew rate are desirable for ~~[illegible]~~ superior performance.

* There are many instrumentation amplifiers such as the μA725, ICL7605 and LH0036, that make a circuit extremely stable and accurate. These ICs are, however relatively expensive, they are precise special purpose circuits in which most of the electrical parameters, such as offsets, drifts and power consumption are minimized where as input resistance, CMRR and supply range are optimized.

Instrumentation amplifier using Transducer Bridge (3)

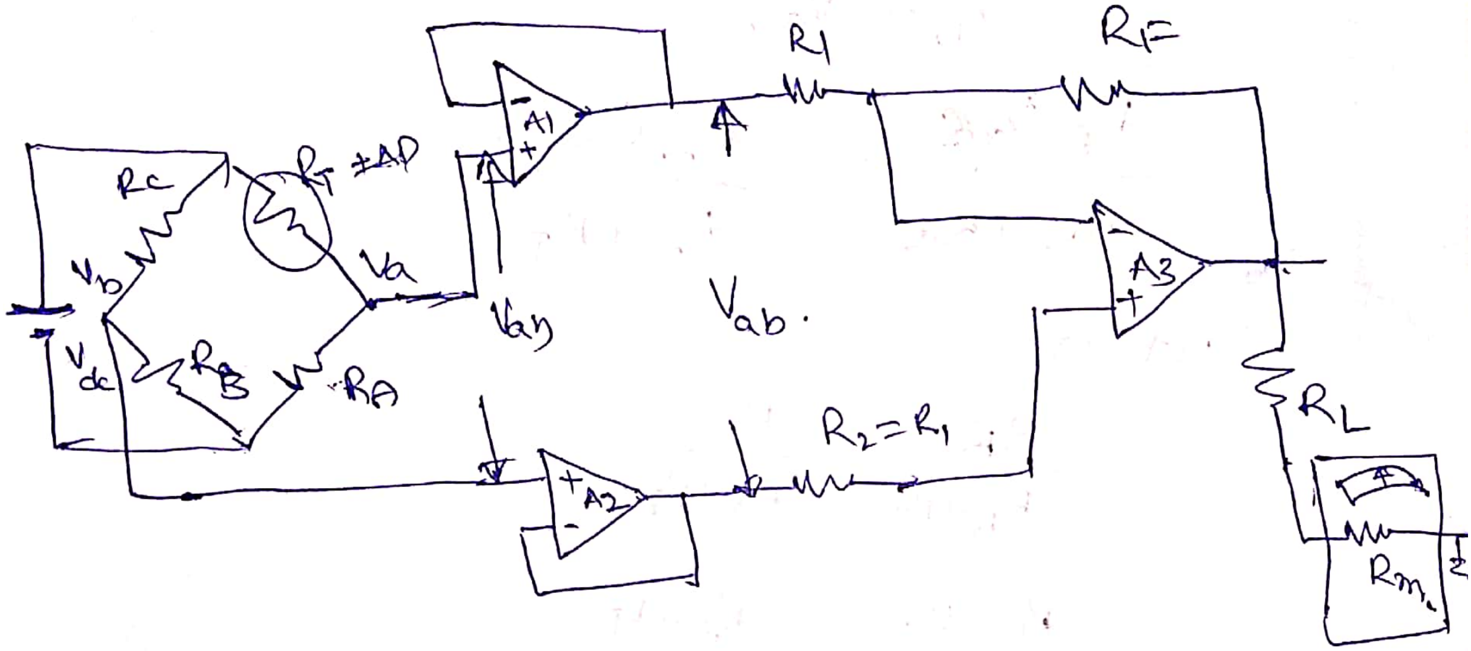

Fig shows a simplified differential instrumentation amplifier using a transducer bridge.

* A resistive transducer whose resistance changes as a function of some physical energy is connected in one arm of the bridge with a small circle around it and is denoted by $(R_T \pm \Delta R)$ where R_T is the resistance of the transducer and ΔR the change in resistance R_T.

The bridge in the circuit is dc but could be ac excited as well.
For the balanced bridge at some reference condition

$$V_b = V_a.$$

$$\frac{R_B V_{dc}}{R_B + R_c} = \frac{R_A (V_{dc})}{R_A + R_T}.$$

That is

$$\frac{R_B}{R_B + R_c} = \frac{R_A}{R_A + R_T}.$$

$$\frac{R_B + R_c}{R_B} = \frac{R_A + R_T}{R_A}$$

$$\cancel{1} + \frac{R_c}{R_B} = \cancel{1} + \frac{R_T}{R_A}.$$

$$\boxed{\frac{R_c}{R_B} = \frac{R_T}{R_A}.}$$

Generally resistors R_A, R_B and R_c are selected so that they are equal in value to the transducer resistance R_T at some reference condition. The reference condition is the specific value of the

averages ...

physical quantity under measurement at which the bridge is balanced.
This value is normally established by the designer and depends on the transducer's characteristics, the type of physical quantity to be measured, and the desired application.

The bridge is balanced initially at a desired reference condition. However as the physical quantity to be measured changes, the resistance of the transducer also changes, which causes the bridge to unbalance ($V_a \neq V_b$). The output voltage of the bridge can be expressed as a function of the change in resistance of the transducer.

Let the change in the resistance of the transducer be ΔR. Since R_B and R_C are fixed resistors, the voltage V_b is constant. However, voltage V_a varies as a function of the change in transducer resistance. Therefore according to the

Voltage divider rule.

$$V_a = \frac{R_A V_{dc}}{R_A + (R_T + \Delta R)}$$

$$V_b = \frac{R_B (V_{dc})}{R_B + R_C}.$$

consequently, the voltage across the output terminals of the bridge is

$$V_{ab} = V_a - V_b$$

$$= \frac{R_A V_{dc}}{R_A + R_T + \Delta R} - \frac{R_B V_{dc}}{R_B + R_C}$$

If $R_A = R_B = R_C = R_T = R$. then.

$$V_{ab} = -\frac{\Delta R (V_{dc})}{2(2R + \Delta R)}$$

The -ve sign in this equation indicates $V_a < V_b$ because of increase in the ΔR.

The Output voltage V_{ab} of the bridge is then applied to the differential instrumentation amplifier composed of three op-amps.

The voltage followers preceding the basic differential amp help to eliminate loading of the bridge circuit.

The gain of the basic differential amplifier is $-R_F/R_1$. Therefore the output voltage V_o of the circuit is

$$V_o = V_{ab}\left(-\frac{R_F}{R_1}\right) = \frac{\Delta R \cdot V_{dc}}{2(2R+\Delta R)} \cdot \frac{R_F}{R_1}$$

Generally the change in the resistance of the transducer ΔR is very small. therefore we can approximate $(2R+\Delta R) \cong 2R$

$$\boxed{V_o = \frac{R_F}{R_1}\,\frac{\Delta R}{4R}\,V_{dc}}$$

V_o is directly proportional to the change in resistance ΔR of the transducer.

Since the change in the resistance is caused by a change in physical energy a meter connected at the output can be calibrated in terms of the units of that physical quality.

Temperature indicator.

The circuit shown in the Fig. can be used as a temperature indicator if the transducer in the bridge circuit is a thermistor and the output meter is calibrated in degrees celsius or Fahrenheit.

* the bridge can be balanced at a desired reference condition for instance 25°c. As the temperature varies from its reference value, the resistance of the thermistor changes and the bridge becomes unbalanced. This unbalanced bridge in turn produces the meter movement. The meter can be calibrated to read a desired temperature range by selecting an appropriate gain for the differential instrumentation amplifier.

* The meter movement is dependent on the amount of imbalance in the bridge, that is the change ΔR in the value of the thermistor resistance. The ΔR for the thermistor, can be determined as follows.

ΔR = (temperature coeffient of resistance) (final temp − reference temp) prob.

In the circuit $R_1 = 1k\Omega$, $R_F = 4.7\,k\Omega$ $R_A = R_B = R_c = 100\,k\Omega$ $V_{dc} = +5V$ and op-amp supply voltages $= \pm 15V$. The transducer is a thermistor with the following specifications. $R_T = 100\,k\Omega$ at a reference temp of $25°c$. temperature coefficient of resistance $= -1k\Omega/°c$ & $1\%/°c$. Determine the output voltage at $0°c$ and at $100°c$

At $25°c$ $R_A = R_B = R_c = R_T = 100\,k\Omega$. therefore the bridge is balanced ($V_a = V_b$) and $V_o = 0V$. However at $0°c$ the change ΔR in the resistance of the thermistor is $\Delta R = \frac{-1k\Omega}{°c}(0°c - 25°c) = 25\,k\Omega$.

Therefore at $0°c$.

$$V_o = \frac{R_F}{R_1} \cdot \frac{\Delta R}{4R} V_{dc}.$$

$$= \frac{4.7 \times \cancel{10^3}}{1 \times \cancel{10^3}} \times \frac{\cancel{25 \times 10^3}}{4 \times \cancel{100 \times 10^3}} \times 5$$

$$\boxed{V_o = 1.47\,V.}$$

Similarly at 100°c

$$\Delta R = \frac{-1 k\omega}{°c}(100°c - 25°c) = -75 k\omega$$

$$V_o = \frac{R_F}{R_1} \cdot \frac{(\Delta R)}{4R} \times V_{dc}.$$

$$= -\frac{4.7 \times 10^3}{1 \times 10^3} \times \frac{\cancel{75}^{3} \times 10^3}{4 \times \cancel{100}_{4} \times 10^3} \times 5.$$

$$\boxed{V_o = -4.41V.}$$

Thus when $V_o = 1.47V$ the meter face can be marked as 0°c, and when $V_o = -4.41V$, it can be marked as 100°c. Note that at 25°c $V_o = 0V$, therefore a center-zero meter is required, thus using the resistance - temperature characteristic of thermistor, the meter can be calibrated from 0° to 100°c.

Temperature controller

A simple and inexpensive temperature control circuit may be constructed by using a thermistor in the bridge circuit and by replacing.

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a meter with a relay in the ckt.
The output of the differential instrumentation amplifier drives a relay that controls the current in the heat-generating ckt. A properly designed ckt should energize a relay when the temp of the termistor drops below a desired value, causing the heat unit to turn on.

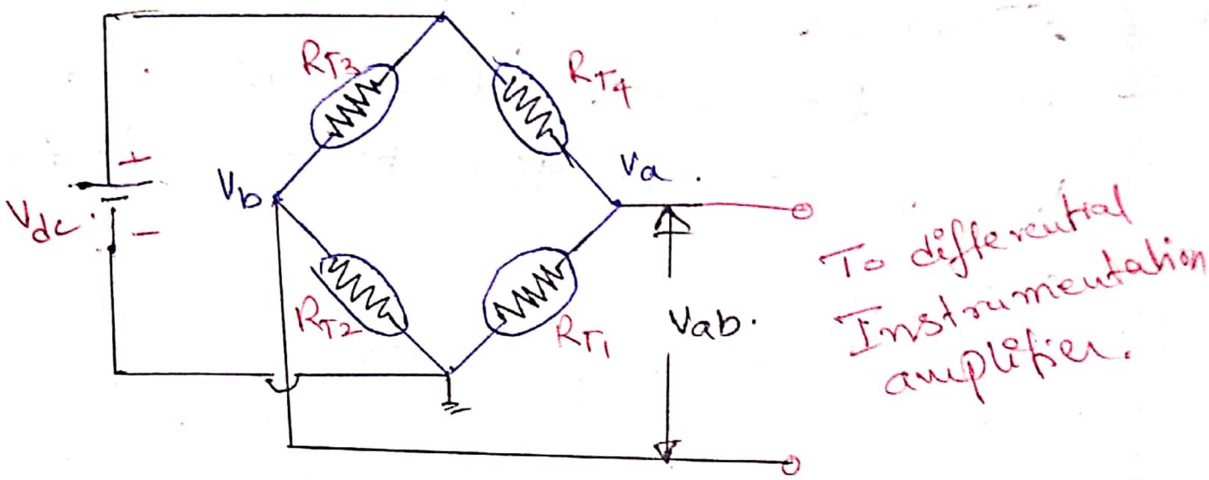
Light-intensity meter.

The circuit in the fig can be used as a light-intensity meter if a transducer is a photocell. The bridge can be balanced for darkness conditions. Therefor when exposed to light, the bridge will be unbalanced and cause the meter to deflect. The meter can be calibrated in terms of 'lux' to measure the change in light intensity.

The light intensity meter using an instrumentation amplifier is more accurate and stable than single-input inverting or noninverting configurations because the common mode (noise) voltages are effectively rejected by differential configuration.

Analog weight Scale.

By connecting a strain gage in the bridge, the ckt in the fig:2 can be converted into a simple and inexpensive analog weight Scale.



In the analog weight scale, straingauge elements are connected in all four arms of the bridge.
The elements are mounted on the base of the weight platform so that, when an external force or weight is applied to the platform, one pair of elements in the opposite arms elongates, whereas the other pair of elements in the opposite compresses.
In otherwords, when the weight is placed on the platform, R_{T_1} and R_{T_3} both decrease in resistance, and R_{T_2} and R_{T_4} both increase in resistance, or vice versa.

when no weight is placed on the platform the bridge is balanced $R_{T_1} = R_{T_2} = R_{T_3} = R_{T_4} = R$ and the output voltage of the weight scale can be zero.

when weight is placed on the scale platform the bridge becomes unbalanced.

Assuming that R_{T_1} and R_{T_3} decreases in resistance and R_{T_2} and R_{T_4} increase in resistance by the same number of ohms ΔR The unbalanced voltage V_{ab} is given by

$$V_a = \frac{(R - \Delta R)\, V_{dc}}{(R - \Delta R) + (R + \Delta R)}$$

$$V_b = \frac{(R + \Delta R)\, V_{dc}}{(R - \Delta R) + (R + \Delta R)}$$

$$V_{ab} = -V_{dc}\frac{\Delta R}{R}.$$

where V_{dc} = dc excitation voltage of the bridge

$R = R_{T_1} = R_{T_2} = R_{T_3} = R_{T_4}$ = unstrained gauge resistance

ΔR = change in gauge resistance

If the decrease in the gauge resistance R_{T_1} and R_{T_3} is ΔR, the increase in resistance of R_{T_2} and R_{T_4} is also ΔR. with this assumption the voltage $V_a < V_b$ and the output voltage V_{ab} is '$-ve$'.

The voltage V_{ab} is then amplified by differential instrumentation amplifier which drives the meter. Since the gain of the amplifier is $\left(-\frac{R_F}{R_1}\right)$ the output voltage V_o is

$$\boxed{V_o = V_{dc}\left(\frac{\Delta R}{R}\right) \cdot \frac{R_F}{R_1}.}$$

The gain of the amplifier can be selected according to the sensitivity of the strain gauge and the fullscale deflection requirements of the meter. The meter can be calibrated in terms of kilograms.

Voltage To - current converter with Floating Load.

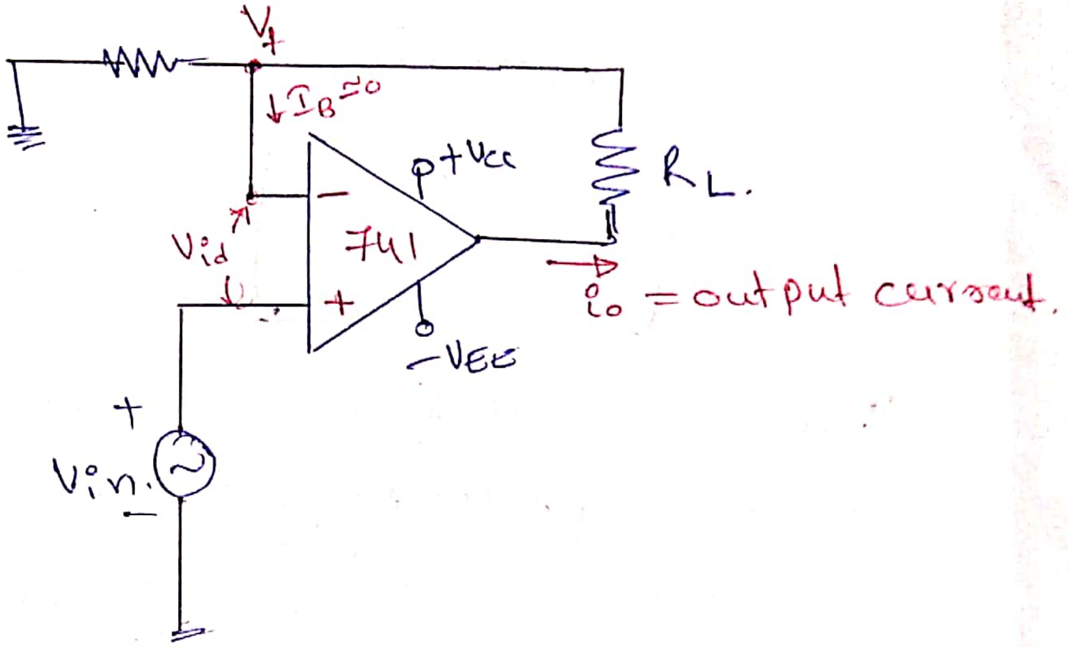


Fig shows a Voltage -to - current converter in which Load Resistance R_L is floating (not connected to ground).

The input voltage is applied to the non inverting input terminal and the feed back voltage across R_1 drives the inverting input terminal.

This circuit is also called a current-series negative feed back amplifier, because the feedback voltage across R_1 (applied to the inverting terminal] depends on the output current i_o and is in series with the input difference voltage V_{id}.

KVL equation for the I/p loop

$V_{in} = V_{id} + V_f$.

But $V_{id} \cong 0\,V$ Since A is very large,

$\therefore V_{in} = V_f$.

$V_{in} = R_1 i_o$.

$$\boxed{i_o = \frac{V_{in}}{R_1}}$$

This means that in the circuit shown in Fig an input voltage V_{in} is converted into an output current of $\frac{V_{in}}{R_1}$. In other words input voltage V_{in} appears across R_1. If R_1 is a precision resistor, the output current ($i_o = V_{in}/R_1$ will be precisely fixed.

The voltage-to-current converted can be used in such applications as Low voltage dc and ac voltmeter, diode match finders, LED & zener diode testers.

(a) Low voltage D.C voltmeter.

If in the converter ckt we replace the Load resistor R_L by an ammeter with a full-scale deflection of 1 mA, the resulting circuit is the dc voltmeter shown in the fig.

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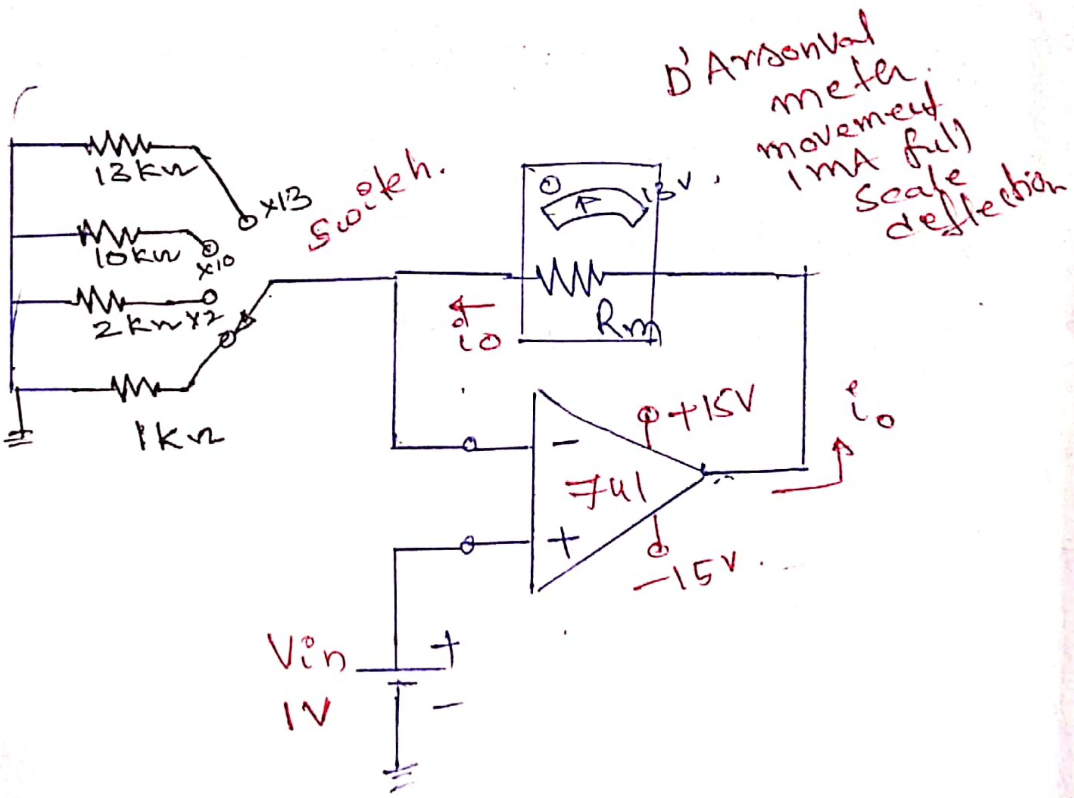


Fig: 2 DC Voltmeter with 1 to 13V Full scale range.

when the switch is in the x1 position

$$I_o = \frac{V_{in}}{R_1} = \frac{1V}{1k\Omega} = 1mA.$$

This means that 1V causes the fullscale deflection of the ammeter.

If the range switch is change to x10 position it will require a 10V input to get full scale deflection. Thus successively higher resistance values are required to measure relatively higher i/p voltages.

However the i/p voltage range for the 741 C op-amp is ±14V. Therefore

with $\pm 15V$ supply voltages, the maximum o/p voltage has to be $\leq \pm 14V$.
The maximum full scale o/p voltage of $\pm 13V$ can be applied when the range switch is in last position.

LOGARITHMIC AMPLIFIER

In the case of a diode

$I = I_0 \left(e^{\frac{V}{\eta V_T}} - 1\right)$. Of is the diode current equation.

I_0 = Reverse saturation current

η = constant, 1 for Ge and 2 for Si.

V_T = Volt eq of temperature $\frac{KT}{q}$ At 300 kelvin 25.85 mV.

V = Applied forward bias Voltage

If V is large. $e^{\frac{V}{\eta V_T}} >> 1$

So $I = I_0 \cdot e^{\frac{V}{\eta V_T}}$.

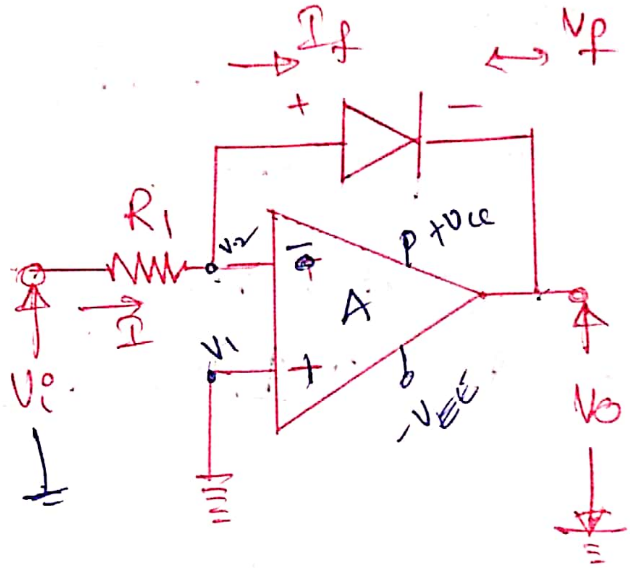
$$\ln I = \ln I_0 + \frac{V}{\eta V_T}$$

$$\boxed{\therefore \quad V = \eta V_T \left[\ln I - \ln I_0\right]}$$

If temperature T is constant, η, V_T and I_0 will be constants. If the diode is connected in feedback path of

5t

the op-amp, the o/p voltage will a logarithmic function of the i/p voltage.



The non-inverting terminal is grounded. So, the inverting terminal will be at the virtual ground point.
Therefore all the input current I flows through the diode.

$$I = I_f$$

$$I = \frac{V_i}{R_1} = I_f.$$

I_f and V_f are related by the diode equation, $V_f = V_o$

$$V_f = \eta V_T (\ln I - \ln I_o)$$

$$V_f = \eta V_T \left[\ln \frac{V_i}{R_1} - \ln I_o \right]$$

$$V_o = -V_f .$$

Hence $V_o \propto \ln(V_i)$.

because of feedback current $I = I_f$.

If changes exponentially with V.

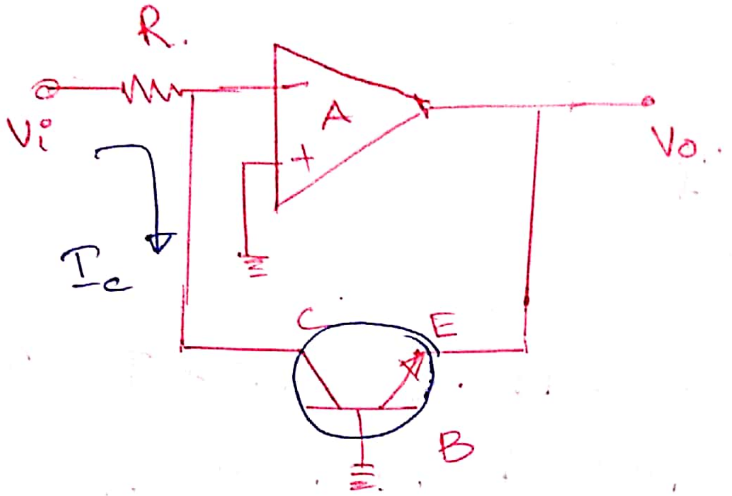
If T change, then Io will change and V_T will change. So the logarithmic variation of Vo with Vi is valid at constant T.

these are used in logarithmic voltmeter to measure voltage from 0V to 1000V on a log scale (with a single scale).

However in the case of diode, the log relation voltage and current in not valid over a very wide range due to finite resistance in the diode.

So in practice, instead of a diode a transistor is used.

If a transistor is operated with V_c, I_c and V_{BE}, they can be related in the form



$V_{BE} = K . \ln I_c .$

where k is constant, $K \propto T$

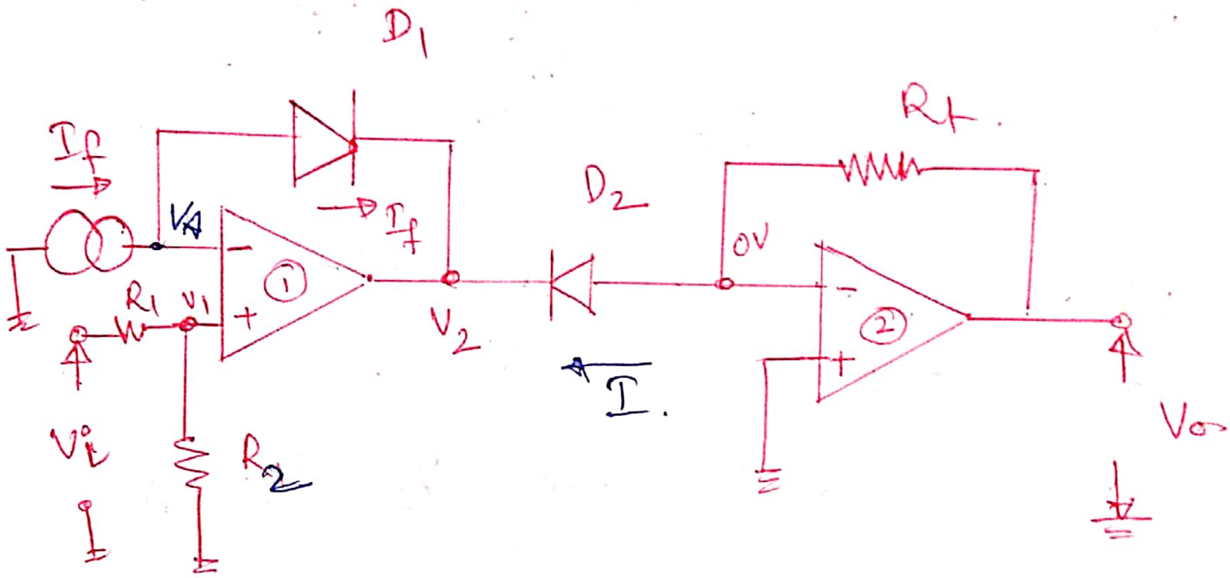
collector is at virtual ground point (Inverting terminal is at 0V). Base is grounded. Therefore $V_{CB} \simeq 0$.

$V_i = I_c R .$

$V_o = V_{BE}$

$$\boxed{\text{So} \quad V_o = k \ln \left[\frac{V_i}{R} \right]}$$

Anti LOGARITHMIC AMPLIFIER



Voltage V_1 at the non-inverting terminal of op-amp (1) is

$$V_1 = \frac{V_i R_2}{R_1 + R_2}$$

op-amp(1) is being used as differential amplifier $V_A \neq V_1$ because the I_f source is connected to the inverting terminal. If R is connected $V_A = V_1$. Voltage V_2 at the output of op-amp (1) is the difference of the voltages at the inverting and non-inverting terminals.

(-)

when the Diode D_1 is forward bias feedback path is a short-circuit term

There fore gain = 1 $V_2 = V_1 - V_A$.

V_A is not a virtual ground point.

$$\text{So } I_f = I_o \cdot e^{\frac{V_o}{\eta V_T}}$$

Diode is forward baised, so it is in closed-loop configuration.

Since diode is short $V_2 = V_1 - V_A$

The Voltage across the diode D_1 is the output of op-amp 1.

It is V_2.

Expression for V_2 is $\eta V_T \left[\ln(I_f) - \ln(I_o) \right]$

The cathode of D_1 need not be grounded.

I_f is the current that flows due to potential difference $(V_A - V_2)$

$$V_2 = \frac{V_i R_2}{R_1 + R_2} - \eta V_T \left[\ln I_f - \ln I_o \right]$$

$$V_2 = V_1 - V_A.$$

(7)

$$I = I_0\left(e^{-\frac{V_2}{\eta V_T}} - 1\right)$$

$$V_2 = -\eta V_T\left[\ln I - \ln I_0\right]$$

Voltage across the diode D_2 is.

$$V_2 = -\eta V_T\left[\ln I - \ln I_0\right]$$

D_2 is Reverse biased.

Voltage across diode D_2 is negative because the anode is at 0V and cathode is at -ve potential.

Therefor eq (2) is in term of I_f and I.

From eq (2)

$$V_2 = \frac{V_i R_2}{R_1+R_2} - \eta V_T\left[\ln I_f - I_0\right]$$

$$-\eta V_T\left[\ln I - \ln I_0\right] = \frac{V_i R_2}{R_1+R_2} - \eta V_T\left[\ln I_f - I_0\right]$$

$$V_i\left[\frac{R_2}{R_1+R_2}\right] = \eta V_T\left[\ln I_f - \ln I_0\right] - \eta V_T\left[\ln I - \ln I_0\right]$$

$$= \eta V_T\left[\ln \frac{I_f}{I}\right]$$

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$I_f \neq I$ because the Voltage across D_1 is $(V_2 - V_A)$. Voltage across D_2 is $-V_2$. current I through a diode follows exponential relation. R of a diode changes according to the current flowing through it.

output voltage V_o at op-amp (2) is

$$V_o = I R_f$$

R_f = feedback Resistor.

$$I = \frac{V_o}{R_f}$$

$$V_i * \frac{R_2}{R_1+R_2} = \eta \cdot V_T \ln \frac{I_f R_f}{V_o}$$

or $$-V_i \frac{R_2}{R_1+R_2} = \eta V_T \ln \frac{V_o}{I_f R_f}.$$

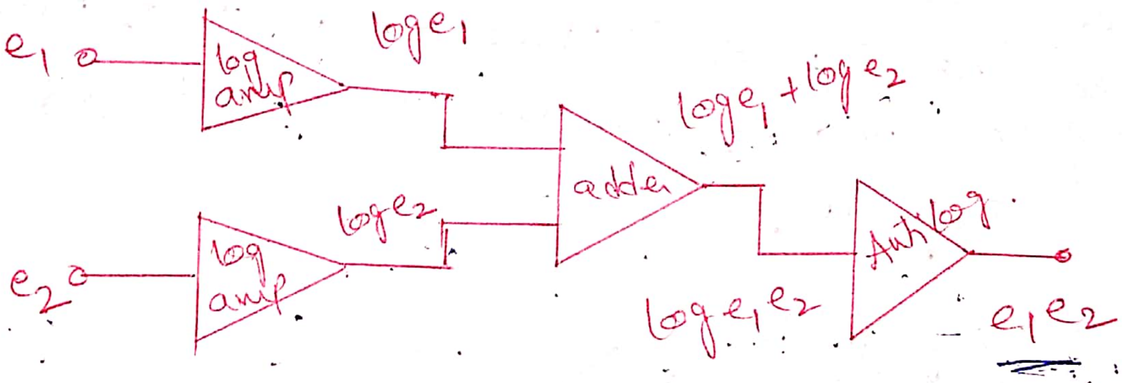
$$\boxed{V_o = I_f R_f \ln^{-1}\left[-V_i \cdot \frac{R_2}{(R_1+R_2)\eta V_T}\right]}$$

D_2 in forward biased, The anode of D_2 is at 0V.

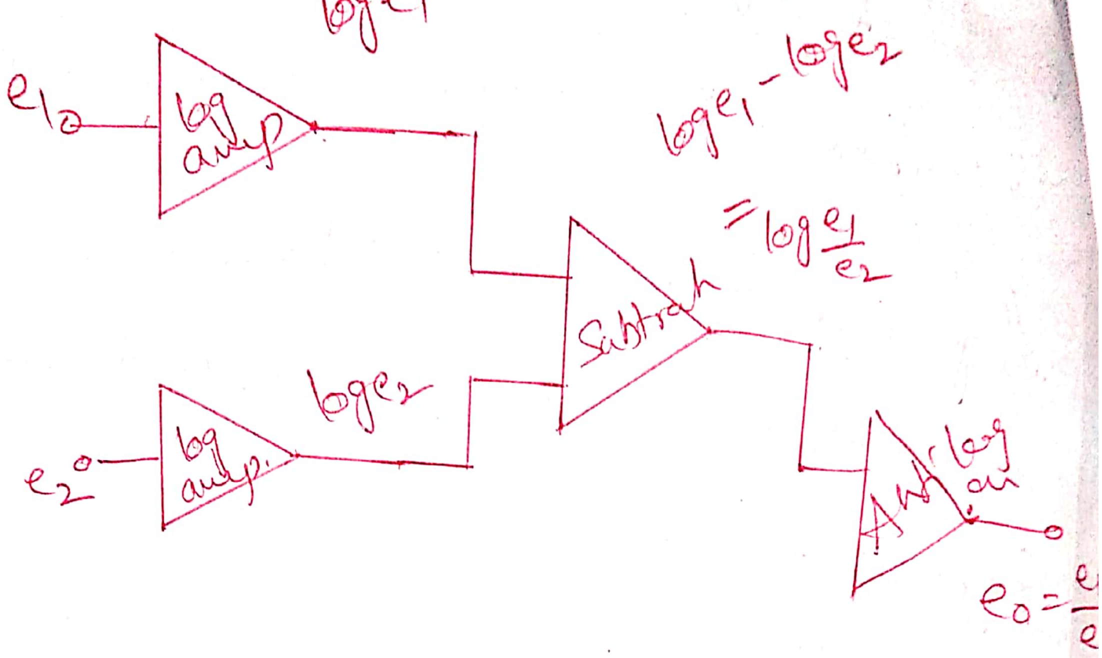
Therefore, the cathode is at -ve potential.

Log and antilog amplifiers are used in analog computers and instrumentation systems.

Log multipliers



Log multiplier circuit.



log Divider circuit.

Log multiplier.

The o/p e_0 is the product of the input e_1 and e_2 can be DC Voltages or AC Signals.

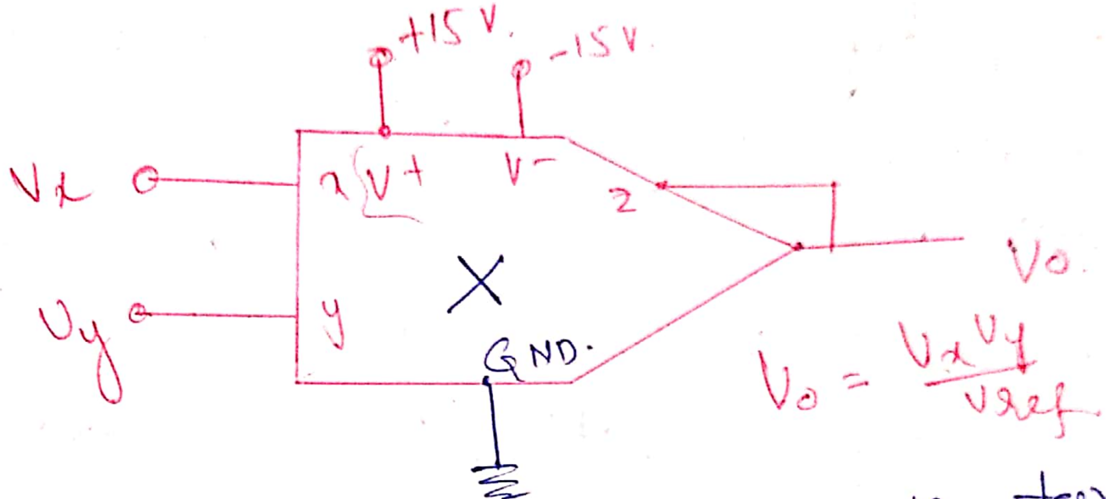
~~log Divider~~

~~The o/p e_0 is the~~

There are a number of applications of analog multiplier such as

* Frequency doubling
* Freq shifting.
* phase angle detection
* Real power computation
* Multiplying two signals, dividing and squaring of signals.

A basic multiplier schematic symbol is shown in fig.



$$V_o = \frac{V_x V_y}{V_{ref}}$$

The o/p is the product of the two i/ps divided by a reference voltage, Vref.

$$V_o = \frac{V_x V_y}{V_{ref}}.$$

Normally V_{ref} is ~~set~~ to 10V. So,

$$V_o = \frac{V_x V_y}{10}.$$

As long as

$V_x < V_{ref}$.

$V_y < V_{ref}$.

The output of the multiplier will not saturate.

If both I/ps are positive, the IC said to be one quadrant multiplier

→ A two quadrant multiplier will function property if one I/p is held positive and the other is allowed to swing both positive and negative.

→ If both I/p may be either positive or negative, the IC is called a four quadrant multiplier.

There can be several ways to make a ckt which will multiply according to eq

$$V_o = \frac{V_x V_y}{V_{ref}}.$$

One commonly used technique is log-antilog method.

This log-antilog method relies on the mathematical relationship that the sum of the logarithm of two numbers equals the logarithm of the product of those numbers.

$$\log V_x + \ln V_y = \ln (V_x V_y)$$

The block dia of a log-antilog (13)
multiplier IC.

Log-amps require the I/p and reference voltages to be the same polarity.

This restricts log-antilog multiplier to one quadrant operation.

A technique that provide four quadrant multiplication in transconduct multiplier.

Some of the multiplier IC chips available are AD533 and AD534.

Application of multiplier IC

Frequency Doubling.

The multiplication of two sine wave of the same frequency, but of possibly different amplitudes and phases allows to double a freq and to directly measure real power.

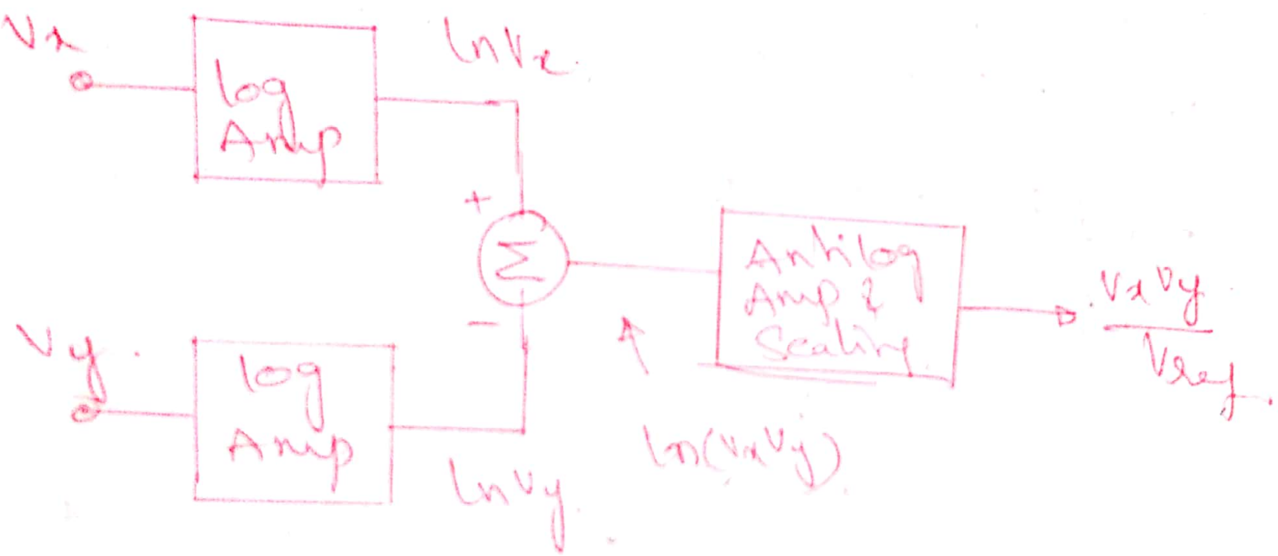
Let $V_x = V_x \sin \omega t$

$V_y = V_y \sin(\omega t + \theta)$

where θ is the phase difference between the two signals.

Applying these two signals to the i/ps of a four quadrant multiplier will yield an o/p as

$$V_o = \frac{V_x \sin\omega t \cdot V_y \sin(\omega t+\theta)}{V_{ref}}$$



$$V_o = \frac{V_x V_y}{V_{ref}} \sin\omega t\left(\sin\omega t\cos\theta + \sin\theta\cos\omega t\right)$$

$$= \frac{V_x V_y}{V_{ref}}\left(\sin^2\omega t\cos\theta + \sin\theta\sin\omega t\cos\omega t\right)$$

$$\sin^2 a = 1 - \cos^2 a.$$

and

$$\cancel{\cos^2 a = 2\cos^2 A \ eq}$$

$$\cos 2A = 2\cos^2 A - 1$$

$$\cos^2 a = \frac{1}{2} + \frac{1}{2}\cos 2a.$$

$$\sin^2 a = 1 - \frac{1}{2} - \frac{1}{2}\cos 2a.$$

$$= \frac{1}{2} - \frac{1}{2}\cos 2a.$$

$$\therefore V_0 = \frac{V_x V_y}{V_{ref}} \left[\cos\theta \left(\frac{1}{2} - \frac{1}{2}\cos 2\omega t \right) + \sin\theta \sin\omega t \cos\omega t \right]$$

But $\sin a \cos a = \frac{1}{2}\sin 2a$

$$\therefore V_0 = \frac{V_x V_y}{2V_{ref}} \left(\cos\theta - \cos\theta \cos 2\omega t + \sin\theta \sin 2\omega t \right)$$

$$V_0 = \frac{V_x V_y}{2V_{ref}} \cos\theta + \frac{V_x V_y}{2V_{ref}} \left(\sin\theta \sin 2\omega t - \cos\theta \cos 2\omega t \right)$$

$$-\cos(2\omega t + \theta)$$

The first term is a DC and is fixed by the magnitude of the signals and their phase differen

The second term varies with time, but at twice the freq of the i/p (2ω).

oneNote for window 10.