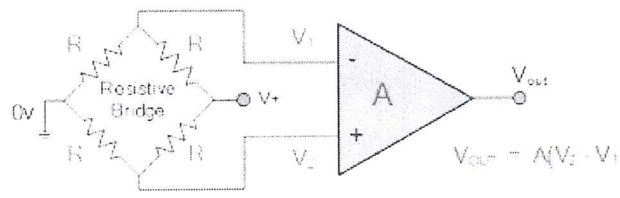
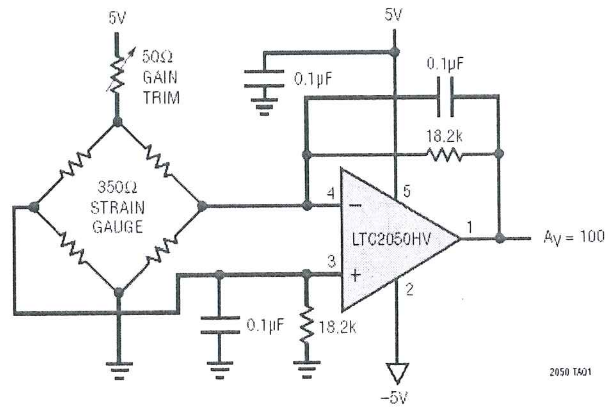
Bridge Amplifiers:

- The output signal from a resistance bridge is usually very small in comparison to the reference signal, and it has to be amplified to increase its voltage level to a useful value (e.g., for use in system monitoring, data logging, or control).

- This is typically an instrumentation amplifier, which is essentially a sophisticated differential amplifier.

- The bridge amplifier is modeled as a simple gain K_a, which multiplies the bridge output.

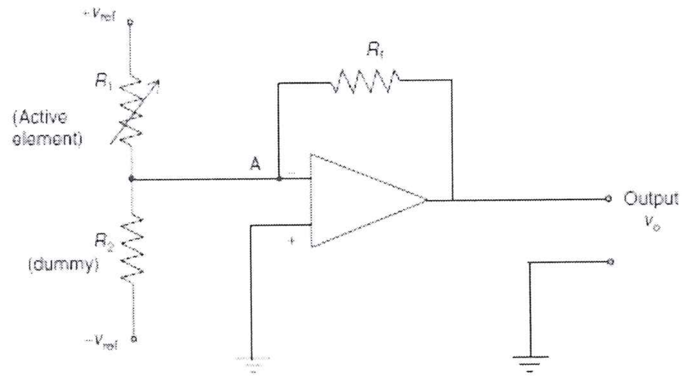




Half-Bridge Circuits:

- A half bridge has only two arms.
- Output is tapped from the mid-point of these two arms.
- The ends of the two arms are excited by two voltages, one of which is positive and the other negative.
- Initially, the two arms have equal resistances so that nominally the bridge output is zero.
- One of the arms has the active element. Its change in resistance results in a nonzero output voltage.
- It is noted that the half-bridge circuit is somewhat similar to a potentiometer circuit (a voltage divider).

The two bridge arms have resistances R_1 and R_2, and the output amplifier uses a feedback resistanceR_f.



To get the output equation, we use the two basic facts for an unsaturated op-amp; the voltages at the two input leads are equal (due to high gain), and the current in either lead is zero (due to high input impedance). Hence, voltage at node A is zero and the current balance equation at node A is given by:

$$\frac{V_{ref}}{R_1} + \frac{-V_{ref}}{R_2} + \frac{V_o}{R_f} = 0$$

which means: $V_o = R_f\left(\frac{1}{R_2} - \frac{1}{R_1}\right) V_{ref}$ — (1)

Assume Initially $R_1 = R_2 = R$; Change R_1 by δR

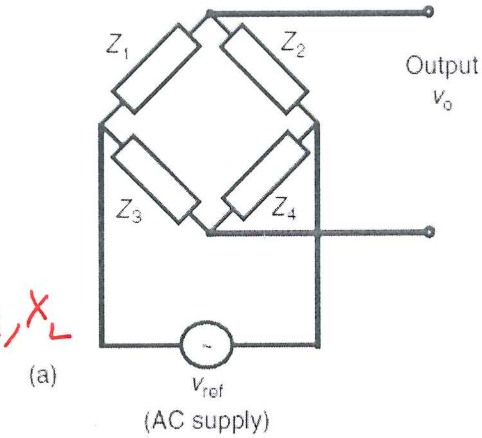
$$\delta V_o = R_f\left(\frac{1}{R} - \frac{1}{R+\delta R}\right) V_{ref} - 0$$ if $R_1 = R_2$ EQ 1 = 0.

$$\frac{\delta V_o}{V_{ref}} = \frac{R_f}{R}\left(\frac{\cancel{R}+\delta R - \cancel{R}}{R+\delta R}\right) = \frac{R_f}{R}\left(\frac{\delta R/R}{1+\delta R/R}\right)$$

R_f/R is the Amplifier gain ; $N_p = 100 \frac{\delta R}{R} \%$.

⇒ Non-Linearity of half bridge is worse than that of wheatstone bridge

Impedance Bridges:



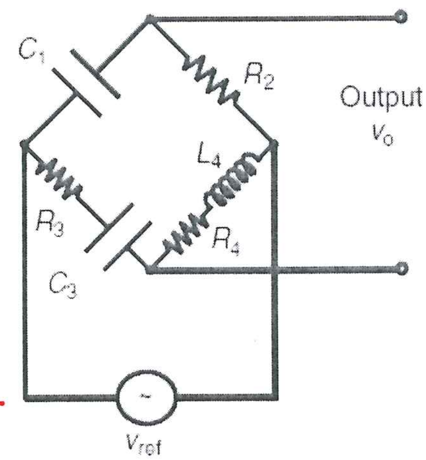
- AC Bridge
- Contains four impedances: Z_1, Z_2, Z_3 *and* Z_4

- V_{ref} : Carrier : AC Supply
- V_o : demodulate
- Bridge can be used to measure X_C, X_L in sensors ∴ Oscillator Circuits as frequency generators

$$v_o(\omega) = \frac{Z_1 Z_4 - Z_2 Z_3}{(Z_1+Z_2)(Z_3+Z_4)} V_{ref}(\omega).$$ AC frequency dependancy

Balanced Condition ⇒ $\frac{Z_1}{Z_2} = \frac{Z_3}{Z_4}$.

Owen Bridge:



Ex. of Measuring C_3 and/or L_4 by balance Method.

Ind: $v = L\frac{di}{dt}$; Cap: $i = C\frac{dv}{dt}$

in Laplace : V–I transfer function.

Inductor: $\frac{v(s)}{i(s)} = L(s)$; Impedance $Z_L = j\omega L$

Capacitor: $\frac{v(s)}{i(s)} = \frac{1}{C(s)}$; Impedance $Z_C = \frac{1}{j\omega C}$

$\therefore Z_1 = \frac{1}{j\omega C_1}$; $Z_2 = R_2$; $Z_3 = R_3 + \frac{1}{j\omega C_3}$; $Z_4 = R_4 + j\omega L_4$; ω = Excitation frequency

For Balanced Bridge $\frac{Z_1}{Z_2} = \frac{Z_3}{Z_4}$; ~~$\frac{R_4 + j\omega L_4}{j\omega C_1}$~~ or $Z_1 \cdot Z_4 = Z_2 \cdot Z_3$

$$\therefore \frac{R_4 + j\omega L_4}{j\omega C_1} = R_2\left(R_3 + \frac{1}{j\omega C_3}\right)$$; Now Equating Real & Imag. Parts.

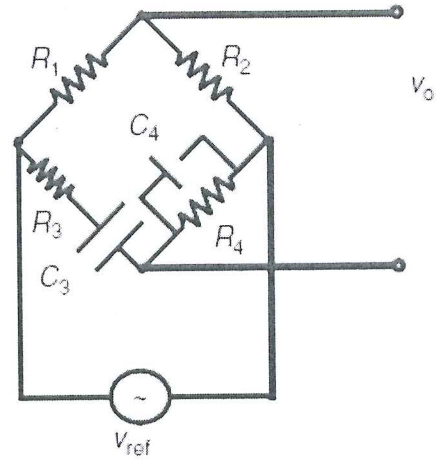
$$\left(\frac{R_4}{j\omega C_1} + \frac{\cancel{\omega} L_4}{\cancel{\omega} C_1} = R_2 R_3 + \frac{R_2}{j\omega C_3}\right) \Rightarrow \frac{L_4}{C_1} = R_2 R_3 \text{ and } \frac{R_4}{C_1} = \frac{R_2}{C_3}$$

$L_4 = C_1 R_2 R_3$ and $C_3 = \frac{R_2 C_1}{R_4}$

- L_4, C_3 can be obtained by C_1, R_2, R_3, R_4 under balanced conditions.
- Fix C_1 and R_2 : Adjustable R_3 can be used to measure Variable L_4

- Adjustable R_4 can be used to measure Variable C_3

Wien Bridge Oscillator:



In this circuit, we have

$Z_1 = R_1$; $Z_2 = R_2$

$Z_3 = R_3 + \frac{1}{j\omega C_3}$

$\frac{1}{Z_4} = \frac{1}{R_4} + j\omega C_4$; Admittance

Bridge to be balanced $\Rightarrow$

$$\frac{R_1}{R_2} = \left(R_3 + \frac{1}{j\omega C_3}\right) \cdot \left(\frac{1}{R_4} + j\omega C_4\right)$$

Equating Real Parts:

$$\frac{R_1}{R_2} = \frac{R_3}{R_4} + \frac{C_4}{C_3}$$

Imaginary Parts

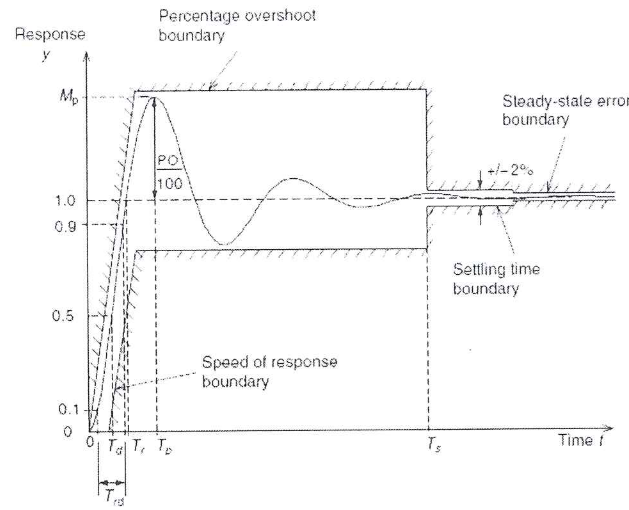
$$0 = \omega C_4 R_3 - \frac{1}{\omega C_3 R_4} \quad \left(\text{Note } j = -\frac{1}{j}\right)$$

$$\therefore \omega C_4 R_3 = \frac{1}{\omega C_3 R_4} \quad \text{or} \quad \omega^2 = \frac{1}{C_3 R_4 C_4 R_3}$$

or $$\omega = \frac{1}{\sqrt{C_3 R_4 C_4 R_3}}$$; Oscillator Natural frequency Underbalanced Equations.

- Circuit can be used to measure Unknown Resistance (in strain gage) by measuring (1st) frequency of bridge at Resonance.

Response parameters for time-domain specification of performance:



Delay Time:
This is usually defined as the time taken to reach 50% of the steady-state value for the first time. This parameter is also a measure of speed of response.

Peak Time
The time at the first peak of the device response is the peak time. This parameter also represents the speed of response of the device.

Settling Time
This is the time taken for the device response to settle down within a certain percentage (typically+2%) of the steady-state value. This parameter is related to the degree of damping present in the device as well as the degree of stability.

Percentage Overshoot
This is defined as, $PO = 100(M_P - 1)\%$, using the normalized-to-unity step response curve, where M_P is the peak value. Percentage overshoot (PO) is a measure of damping or relative stability in the device.

Simple Oscillator Model:

- Represents Performance of Various devices
- Depending on the level of damping: Oscillatory and Non-Osc. behaviour can be represented. Model can be expressed as:

$$\ddot{y} + 2\xi\omega_n\dot{y} + \omega_n^2 y = \omega_n^2 u(t);$$

u: excitation.
ω_n: Undamped Natural f
ξ: Damping Ratio

Damped Natural frq: $\omega_d = \sqrt{1-\xi^2}\,\omega_n$

If excitation is STEP FUNCTION with ZERO initial Conditions is:

$$y = 1 - \frac{1}{\sqrt{1-\xi^2}} e^{-\xi\omega_n t} \cdot \sin(\omega_d t + \phi)$$

$$\cos\phi = \xi$$

For a transducer: desired to have Small rise time, Small settling time

TABLE 3.1

Time-Domain Performance Parameters Using the Simple Oscillator Model

Performance Parameter	Expression
Rise Time	$T_r = \dfrac{\pi - \phi}{\omega_d}$ with $\cos\phi = \zeta$
Peak Time	$T_p = \dfrac{\pi}{\omega_d}$
Peak Value	$M_p = 1 - e^{-\pi\zeta/\sqrt{1-\zeta^2}}$
Percentage Overshoot (PO)	$PO = 100\, e^{-\pi\zeta/\sqrt{1-\zeta^2}}$
Time Constant	$\tau = \dfrac{1}{\zeta\omega_n}$
Settling Time (2%)	$T_s = -\dfrac{\ln\left[0.02\sqrt{1-\zeta^2}\right]}{\zeta\omega_n} \approx 4\tau = \dfrac{4}{\zeta\omega_n}$

An automobile weighs 1000 kg. The equivalent stiffness at each wheel, including the suspension system, is approximately 60.0×10^3 N/m. If the suspension is designed for a percentage overshoot of 1%, estimate the damping constant that is needed at each wheel.

Solution: using a Simple oscillator Model of the form

$m\ddot{y} + b\dot{y} + ky = k u(t)$; m = mass = 250 (each W: 1000/4 = 250), b = damping constant

k = equivalent stiffness = 60×10^3 N/m

u = displacement excitation @ each wheel

P.O = 1% .

$250\ddot{y} + b\dot{y} + ky = k u(t)$

$\ddot{y} + \dfrac{b}{m}\dot{y} + \dfrac{k}{m}y = \left(\dfrac{k}{m}\right)u(t)$

$\dfrac{k}{m} = \omega_n^2 \rightarrow \omega_n = \sqrt{\dfrac{k}{m}}$; $\dfrac{b}{m} = 2\zeta\omega_n \Rightarrow \zeta = \dfrac{b}{2\sqrt{km}}$

From Table above (for percent overshoot - P.O)

$1 = 100\, e^{\left(\frac{-\pi\zeta}{\sqrt{1-\zeta^2}}\right)} \Rightarrow \zeta = 0.83$, substitute

$0.83 = \dfrac{b}{2\sqrt{60 \times 10^3 \times 250}} = 6.43 \times 10^3$ N/m/sec.

Active Transducer:

- External power is required to operate active sensors/transducers, and they do not depend on their own power conversion characteristics for operation.
- A good example for an active device is a resistive transducer, such as a potentiometer, which depends on its power dissipation through a resistor to generate the output signal.
- Note that an active transducer requires a separate power source (power supply) for operation,

Passive transducer:

- Draws its power from a measured signal (measurand).
- Since passive transducers derive their energy almost entirely from the measurand, they generally tend to distort (or load) the measured signal to a greater extent than an active transducer would. Precautions can be taken to reduce such loading effects.
- On the other hand, passive transducers are generally simple in design, more reliable, and less costly.
- For example, a piezoelectric charge generation is a passive process. But, a charge amplifier, which uses an auxiliary power source, would be needed by a piezoelectric device in order to condition the generated charge.

Error Analysis:

- Error = (instrument reading) – (true value)
- Measurement Accuracy: Determines the closeness of the measured value to the true value
- Instrument Accuracy: Related to the worst accuracy obtainable within the dynamic range of the instrument in a specific operating environment