NE418 Nuclear Power Plant Instrumentation

Topics

* Basics Circuits Review
* Operational Amplifier Circuit Analysis
* Operating Principles of Gas Filled Ionization Chambers
* Neutron Sensitive Ionization Chambers
* Temperature Measurement and Response Time
* Reactor Coolant Pressure, Level and Flow Measurement
Overview: System with Sensors, Displays and Controls
Examples of Reactors
Instrumentation
Example: Reactor plant control systems. (FC: Frequency Converter; HC: Hydraulic Coupling.)

Example: Integrated Digital Control System

FMCRD: Fine Motion Control Rod Drive
ECCS: Emergency Core Cooling System
BOP: Balance Of Power
RMU: Remote Monitor Unit

Example: Reactor control system for a Japanese ABWR

Example: Reactor vessel coolant level instrumentation system

RTD: Resistance Temperature Detector

NR, WR: Narrow and Wide Range transmitters

Why review circuits and Operational Amplifiers

- Sensors measure events and monitor changes
- Data transferred to electrical signals via data acquisition systems
- Signals may be amplified to reach noticeable levels for acquisition.
- May need filters (low pass, high pass or band pass)
- Data are displayed on monitors.
- Data may pass through comparators to determine if feedback is needed to provide control
- Hence, quick review of circuits is needed
Basic Circuits Review

Circuit model of **physical** system

![Circuit Model Diagram]

**Detector** (Source) → **Amplifier** (Circuit) → **Display Unit** (Load)

Frequency response  \[ H_v(j\omega) = \frac{V_L(j\omega)}{V_S(j\omega)} \]
Thevenin’s equivalent circuit

\[ Z_T = \left( Z_S + Z_1 \right) \parallel Z_2 \]

\[ V_T = V_S \frac{Z_2}{Z_S + Z_1 + Z_2} \]
Hence, the frequency response is given by

\[
V_L(j\omega) = \frac{Z_L}{Z_L + Z_T}V_T
\]

\[
= \frac{Z_L}{Z_L + \frac{(Z_S + Z_1)Z_2}{Z_S + Z_1 + Z_2}}\quad V_S = \frac{Z_LZ_2}{Z_L(Z_S + Z_1 + Z_2) + (Z_S + Z_1)Z_2}V_S
\]

\[
\therefore \frac{V_L(j\omega)}{V_S(j\omega)} = H_V(j\omega) = \frac{Z_LZ_2}{Z_L(Z_S + Z_1 + Z_2) + (Z_S + Z_1)Z_2}
\]

\(V_L(j\omega)\) is a phase-shifted amplitude-scaled version of \(V_S(j\omega)\).

The effect of inserting a linear circuit between a source and a load is that for any given frequency, \( \omega \), the load voltage is a sinusoid at the same frequency as the source Voltage, with amplitude given by

\[
V_L = |H_V| \cdot V_S
\]

and phase equal to \( \phi_L = \phi_H + \phi_S \), where \( |H_V| \) is the magnitude of the frequency response and \( \phi_H \) is its phase angle.

Both \( |H_V| \) and \( \phi_H \) are functions of frequency.