ELECTRONIC SYSTEMS

• COMMUNICATION SYSTEMS
• INTERNET AND COMPUTER SYSTEMS
• DEEP SPACE PROBE SYSTEMS
• BIOMEDICAL SYSTEMS (NERVOUS SYSTEM)
COMMUNICATION SYSTEM

- **MICROPHONE/CAMERA**
  - FILTER
  - AMP
  - MODULATOR
  - FILTER
  - AMP
  - TRANSMITTER ANTENNA

- **RECEIVER ANTENNA**
  - FILTER
  - AMP
  - DEMODULATOR
  - FILTER
  - AMP
  - SPEAKER/MONITOR

- **OSC**
  - AMP
  - FILTER
  - AMP
  - OSC
DATA ACQUISITION SYSTEM

- 4:1 MUX
- AMP
- SAMPLE AND HOLD
- AMP
- ANALOG TO DIGITAL CONVERTER
- DIGITAL OUTPUTS

- DIGITAL TO ANALOG CONVERTER
- FILTER
- AMP
- ANALOG OUTPUT

ANALOG INPUTS

DIGITAL INPUTS
SIGNALS

- LARGE SIGNALS OR DC
- SMALL SIGNAL OR AC
- ANALOG
- DIGITAL
TOTAL SIGNAL

• LARGE OR DC STATIC COMPONENT

• SMALL OR AC TIME-VARYING COMPONENT

• NOTATION – SMALL CASE LETTER WITH LARGE CASE SUBSCRIPT
LARGE SIGNALS

- DEFINE TRANSFER FUNCTION OF CIRCUIT DEVICES

- DC OR STATIC COMPONENT OF TOTAL SIGNAL

- NOTATION – CAPITALIZED LETTER WITH CAPITALIZED SUBSCRIPT
SMALL SIGNALS

- USED TO REPRESENT INFORMATION PROCESSED BY CIRCUIT DEVICE

- DEFINE TRANSFER FUNCTIONS OF ACTIVE CIRCUIT DEVICES

- NOTATION – SMALL CASE LETTER WITH SMALL CASE SUBSCRIPT
TOTAL SIGNAL EXAMPLE

\[ v_D = V_D + v_d \]
ANALOG SIGNALS

• CONTINUOUS TIME VARYING QUANTITIES

• FOUNDATION OF DIGITAL SIGNALS

• USED TO REPRESENT PROCESSED INFORMATION AND UNDESIRED INFORMATION (NOISE)
DIGITAL SIGNALS

• CHARACTERIZED BY TWO OR MORE VOLTAGE OR CURRENT LEVELS

• QUANTIZED OR DISCRETE ANALOG SIGNALS

• USED TO REPRESENT COMPUTER CODED INFORMATION
FREQUENCY SPECTRUM

• AUDIO

• VIDEO

• BODE PLOTS

• DECIBEL NOTATION
AUDIO FREQUENCY SPECTRUM

- LOW LIMIT – 20 TO 30 HERTZ
- HIGH LIMIT – 20,000 TO 30,000 HERTZ
- LOW FREQUENCY ANALYSIS AND DESIGN
VIDEO FREQUENCY SPECTRUM

• LOW LEVEL – 5 MEGAHERTZ

• HIGH LEVEL – 500 MEGAHERTZ

• HIGH FREQUENCY ANALYSIS AND DESIGN
BODE PLOTS

• POWER OR MAGNITUDE OF INFORMATION VERSUS FREQUENCY

• PHASE ANGLE VERSUS FREQUENCY

• MODEL OF SIGNAL QUALITY VERSUS FREQUENCY
MAGNITUDE VERSUS FREQUENCY PLOT
PHASE ANGLE VERSUS FREQUENCY PLOT

$\phi(f)$ vs $\log f$
DECIBEL NOTATION

- USED TO PROVIDE MEASUREMENT OF SIGNALS WITH LARGE VALUES
- USED TO PROVIDE MEASUREMENT OF SIGNALS OVER WIDE FREQUENCY SPECTRUM
DECIBEL NOTATION

\[ P_{dB} = 10 \log P \quad \rightarrow \text{Power Measurement} \]

\[ G_{dB} = 10 \log \left( \frac{P_o}{P_i} \right) \quad \rightarrow \text{Power Gain} \]

\[ A_{v,dB} = 20 \log \left( \frac{v_o}{v_i} \right) \quad \rightarrow \text{Voltage Gain} \]
POWER GAIN EXAMPLE

\[ P_I = 10W \quad P_O = 1000W \]

\[ G = 10\log\left(\frac{1000W}{10W}\right) \quad \rightarrow \quad G = 10\log(100) \]

\[ G = ? \, dB \]
VOLTAGE GAIN EXAMPLE

\[ V_I = 0.1V \quad \quad V_O = 10V \]

\[ A_V = 20 \log \left( \frac{10V}{0.1V} \right) \quad \rightarrow \quad A_V = 20 \log(100) \]

\[ A_V = ? dB \]
ELECTRONIC CIRCUITS

• RESISTORS

• CAPACITORS

• POWER SOURCES

• ACTIVE DEVICES
ACTIVE DEVICES

- DELIVER SUSTAINED POWER
- CONTROL THE FLOW OF ENERGY
- MODELED BY PASSIVE COMPONENTS
ACTIVE DEVICES

- DIODES
- TRANSISTORS
- AMPLIFIERS
AMPLIFIERS

• PRODUCES MAGNIFIED VOLTAGE, CURRENTS, OR POWER

• THREE OR MORE TERMINAL DEVICE

• COMPRISED OF ACTIVE AND PASSIVE COMPONENTS
AMPLIFIER CHARACTERISTICS

• GAIN

• INPUT AND OUTPUT IMPEDANCE

• BANDWIDTH

• LINEARITY
AMPLIFIER SYMBOL

\[ v_{\text{in}} \rightarrow A \rightarrow v_{\text{out}} \]
VOLTAGE AMPLIFIER MODEL

\[ v_{out} = -A_{VO} \cdot v_{in} \]

\[ v_{in} \]

\[ R_{in} \]

\[ R_{out} \]
AMPLIFIER WITH SOURCE AND LOAD

SOURCE

AMPLIFIER

LOAD

\( R_{SIG} \)

\( i_{in} \)

\( v_{in} \)

\( v_{in} \)

\( v_{out} \)

\( A_{VO} v_{in} \)

\( R_{IN} \)

\( R_{OUT} \)

\( i_{out} \)

\( v_{out} \)

\( R_{L} \)
VOLTAGE EQUATIONS

\[ v_{in} = \left( \frac{R_{IN}}{R_{SIG} + R_{IN}} \right) v_{sig} \]

\[ v_{out} = \left( \frac{R_L}{R_{OUT} + R_L} \right) \left( A_{VO} v_{in} \right) \]
VOLTAGE GAIN

\[ \frac{v_{out}}{v_{in}} = \frac{A_{VO} R_L}{R_{OUT} + R_L} \]

\[ A_V \equiv \frac{v_{out}}{v_{in}} \]

\[ A_V = \frac{A_{VO} R_L}{R_{OUT} + R_L} \]
VOLTAGE GAIN

\[
\frac{v_{out}}{v_{sig}} = \left( \frac{v_{out}}{v_{in}} \right) \left( \frac{v_{in}}{v_{sig}} \right)
\]

\[
\frac{v_{out}}{v_{sig}} = \left( \frac{A_{VO}R_L}{R_{OUT} + R_L} \right) \left( \frac{R_{IN}}{R_{SIG} + R_{IN}} \right)
\]

\[
\frac{v_{out}}{v_{sig}} = A_V \left( \frac{R_{IN}}{R_{SIG} + R_{IN}} \right)
\]
CURRENT GAIN

\[
i_{out} = \frac{v_{out}}{R_L} \quad i_{in} = \frac{v_{in}}{R_{in}}
\]

\[
\frac{i_{out}}{i_{in}} = \left(\frac{v_{out}}{R_L}\right)\left(\frac{R_{in}}{v_{in}}\right)
\]

\[
\frac{i_{out}}{i_{in}} = \left(\frac{v_{out}}{v_{in}}\right)\left(\frac{R_{in}}{R_L}\right)
\]
CURRENT GAIN

\[
\frac{i_{out}}{i_{in}} = \left( \frac{v_{out}}{v_{in}} \right) \left( \frac{R_{in}}{R_L} \right) \quad \rightarrow \quad \frac{i_{out}}{i_{in}} = A_V \left( \frac{R_{in}}{R_L} \right)
\]

\[
\frac{i_{out}}{i_{in}} = \left( \frac{A_{VO} R_L}{R_{out} + R_L} \right) \left( \frac{R_{in}}{R_L} \right) \quad \rightarrow \quad A_I = \left( \frac{A_{VO} R_L}{R_{out} + R_L} \right) \left( \frac{R_{in}}{R_L} \right)
\]
POWER GAIN

\[ P_{out} = v_{out} \cdot i_{out} \quad \text{and} \quad P_{in} = v_{in} \cdot i_{in} \]

\[ \frac{P_{out}}{P_{in}} = \left( \frac{v_{out}}{v_{in}} \right) \left( \frac{i_{out}}{i_{in}} \right) \]

\[ \frac{P_{out}}{P_{in}} = A_v A_I \]
POWER GAIN

\[ \frac{P_{out}}{P_{in}} = A_V A_I \]

\[ \frac{P_{out}}{P_{in}} = \left( \frac{A_{VO} R_L}{R_{out} + R_L} \right)^2 \left( \frac{R_{in}}{R_L} \right) \]
POWER GAIN CALCULATIONS

\[
\frac{P_{\text{out}}}{P_{\text{in}}} = A_V A_I
\]

\[
\frac{P_{\text{out}}}{P_{\text{in}}} = A_V^2 \left( \frac{R_{\text{in}}}{R_L} \right)
\]

\[
\frac{P_{\text{out}}}{P_{\text{in}}} = A_I^2 \left( \frac{R_L}{R_{\text{in}}} \right)
\]
INPUT IMPEDANCE (RESISTANCE)

\[ R_I = \frac{V_{IN}}{I_{IN}} \]

\[ R_I = R_{IN} \]
OUTPUT IMPEDANCE

\[ R_O = \frac{v_{OUT}}{i_{OUT}} \]

\[ R_O = R_{OUT} \]
BANDWIDTH
DIRECT COUPLED

\[ A_v \]

\[ A_{VMID} \]

\[ A_{VMID} \times 0.707 \]

BW

\[ f_B \]

\[ f_T \]

log f
BANDWIDTH
AC COUPLED

\[ A_{\text{VMID}} \]
\[ A_{\text{VMID}} \times 0.707 \]

\[ f_{BL} \]
\[ f_{BH} \]
\[ f_T \]

\[ \text{BW} \]
DECIBEL

\[ A_{V_{dB}} = 20 \log \left( \frac{V_{OUT}}{V_{IN}} \right) \rightarrow A_{V_{dB}} = 20 \log A_V \]

\[ A_{I_{dB}} = 20 \log \left( \frac{I_{OUT}}{I_{IN}} \right) \rightarrow A_{I_{dB}} = 20 \log A_I \]
LINEARITY

vout

vin

ideal

actual
CASCADED AMPLIFIERS

• USED TO INCREASE GAIN OF A MULTI-STAGE AMPLIFIER

• GAIN IS APPROXIMATELY PRODUCT OF EACH AMPLIFIER
CASCADED AMPLIFIERS

• INPUT IMPEDANCE CHARACTERIZED BY FIRST STAGE

• OUTPUT IMPEDANCE CHARACTERIZED BY LAST STAGE
CASCADED AMPLIFIER

\[ v_{out} = (A_1)(A_2)(A_3)(A_4)v_{in} \]
INTEGRATED CIRCUIT

- COMPLETE CIRCUIT FABRICATED ON SEMICONDUCTOR MATERIAL
- HIGH SPEED ANALOG AND DIGITAL CIRCUITS
- MIXED SIGNAL CIRCUITS
INTEGRATED CIRCUIT COMPONENTS

- RESISTORS

- CAPACITORS

- DIODES

- TRANSISTORS
POWER SUPPLIES

• MOSTLY DISCRETE

• CONTEMPORARY HYBRID

• SOME INTEGRATED