

## Transistor Amplifiers and Oscillators

Amplifiers require *negative feedback* (180° out-of-phase) for circuit stability, high fidelity, wide bandwidth

Oscillators require *positive feedback* (in-phase) in order to sustain operation

Oscillators convert DC supply voltages to AC signals

Piezoelectric Effect (Crystal Control)

Vibrates when immersed in an electric field and generates current when physically deformed

Common Emitter (BJT) Amplifiers

Low frequency cut-off due to coupling capacitors and by-pass capacitors

High frequency cut-off due internal junction capacitance and frequency dependence of  $\beta$

Amplifier Gain (Generally expressed as Gain = Output / Input)

Gain Factors are defined for Voltage, Current, and Power

Voltage Gain is often expressed using slightly different symbology ( $\alpha$ ,  $A$ ,  $A_0$ ,  $A_v$ ).

Current Gain  $A_i$

Power Gain  $A_p$

## Operational Amplifiers (Op-Amps)

Series of cascaded amplifiers:

differential amplifier, high gain voltage amplifier, low impedance output amplifier.

Characteristics of input and output impedance, voltage gain, bandwidth for an ideal op-amp:

high input impedance, low output impedance, high gain, wide bandwidth.

$V_{sat} = V_{CC} \pm 2 \text{ volts}$        $+V_{sat} (\text{Max } V_{out}) = +V_{CC} - 2 \text{ V}$        $-V_{sat} (\text{Max } V_{out}) = -V_{CC} + 2 \text{ V}$

Basic Rule for Input Currents:  $i^- = i^+ = 0$

**Open Loop** (no feedback):  $V_{out} = A(v^+ - v^-)$  such that  $V_{out} = V_{sat}$

Comparators: Protects against inadvertent output switching due to noisy input signals.

**Closed Loop** (positive feedback)

Schmitt Triggers: Bi-reference level comparator with positive feedback.

**Closed Loop** (negative feedback)

Basic Rule for Input Voltages:  $v^- = v^+$

Gain:

Inverting (input to  $v^-$  terminal) =  $-Z_f / Z_i$

Non-Inverting (input to  $v^+$  terminal) =  $1 + Z_f / Z_i$

Commonly used as summers, multipliers, differentiators, integrators; hence the name *operational amplifiers* (analog computers). Can also be configured as log and anti-log (exponentiation) amplifiers, active filters, unity buffers, comparators, Schmitt triggers, oscillators.

## Differential Mode and Common Mode Operation

Differential Voltage  $V_{DV} = v^+ - v^-$

Differential Gain  $DG = |V_{out} / V_{DV}|$

Common Mode Voltage  $V_{CMV} = (v^+ + v^-) / 2$

Common Mode Gain  $CMG = |V_{out} / V_{CMV}|$

Common Mode Rejection Ratio  $CMRR = DG / CMG$

$CMRR \text{ dB} = 20 \log(DG/CMG)$

Ideal  $CMG = 0$   $CMRR = \infty$  Typical Values  $CMRR = 80\text{dB} = 10^4$

Signal Noise Ratio

$SNR_{in} = V_{signal} / V_{noise}$

$SNR_{out} = CMRR * SNR_{in}$

## Operational Amplifiers Handouts and Op-Amp Problems

Operational Amplifier Active Filters

Calculate band pass gain and cut-off frequencies for low and high pass active filters with either non-inverting input or inverting inputs.

Comparators and Schmitt Triggers - Calculate  $V_{ref}$  voltages and describe the operation.