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# Electronics 1 Part 2 (Quickstudy: Academic)

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**ELECTRONICS 1 PART TWO**  
PART 2 of FUNDAMENTALS OF ELECTRONIC DEVICES & BASIC ELECTRONIC CIRCUITS

### OPERATIONAL AMPLIFIERS

#### DEFINITIONS

- A basic differential amplifier (see *Microelectronics Part One*) makes mathematical difference operation and can be modified to perform addition, integration and differentiation. Hence, the differential amplifier is also designated as an **Operational Amplifier (Op-Amp)**.
- An Op-Amp represents, in essence, a high-gain electronic circuit intended to amplify the difference in the signal voltages applied to its two input terminals, namely, inverting (-) and non-inverting (+) inputs (Fig. 1).
- In simple form (Fig. 2), an Op-Amp simulates a differential amplifier made up of, for example, a pair of BJTs driven by a constant current source (i.e., JFETs and MOSFETs can also be used in differential pairs).

#### IDEAL OP-AMP CHARACTERISTICS

- Nominal voltage gain,  $A_v \rightarrow \infty$
- Input impedance (at both inputs),  $Z_{in} \rightarrow \infty$
- Output impedance,  $Z_o \rightarrow 0$
- Both transistors are identical.
- $A_{v1} = A_{v2} = A_{v(d)} = \infty$ ,  $F_{max} = f_{max} = \infty$
- Gain-bandwidth (GBW) is  $\infty$ .
- With bipolar transistors, it may be difficult to achieve a very high input impedance.
- JFET and MOSFET provide high-input impedance capabilities.

#### OP-AMP OPERATIONAL PARAMETERS

An **offset voltage** (Fig. 3) always exists when inverting (Fig. 4) results of operational characteristics.

- INPUT BIAS CURRENT:** This is the smaller current in the differential amplifier for active region operation of the pair of BJTs (e.g., 600pA for the 741 OP-AMP) which comes through  $R_1$  so that  $V_{os} = -IB \times R_1 \times R_2/R_1$  volts. This could be large enough to saturate the output. Saturation is overcome by introducing  $R_2 = R_1 R_2/R_1$  and made adjustable to compensate for input offset current due to any discontinuities in the differential pair configuration (Fig. 5).
- INPUT OFFSET VOLTAGE ( $\pm 100\mu V$ ):** It is required at the input as a counter voltage to offset the offset voltage due to unequal current flowing through the differential pair devices in the OP-AMP, so that this balancing gives zero output voltage.
- CMRR:** When the OP-AMP is ideally balanced at the input, the output voltage is 0. i.e.,  $V_{os} = 0$  and this circuit can reject common-mode signals due to its common-mode gain ( $A_{cm} = 0$ ). For differential mode signals  $V_{os} = \text{high}$  the gain ( $A_{dm} = \infty$ ). The ratio  $A_{dm}/A_{cm}$ , common-mode rejection ratio (CMRR), in practical OP-AMPS,  $A_{dm} = 0$  and  $A_{cm} = \infty$ , so, CMRR is finite and indicates the extent of balance in the OP-AMP (a figure of merit parameter).
- OUTPUT VOLTAGE SWING:** This is the peak output swing with reference to zero at the output. It is limited by power supply voltages used (e.g., percent of power supply voltage  $\pm V_{cc}$ ).
- INPUT VOLTAGE SWING:** Input common-mode voltage swing is limited by the saturation of the differential amplifier at the input. i.e., 30 percent of power supply voltage  $\pm V_{cc}$ .

#### LINEAR RATE:

 Maximum rate at which the output voltage can change (involves slew-rate). In ideal OP-AMP, slew-rate is  $\infty$ .

#### OTHER PARAMETERS:

- (1) Bandwidth; (2) Maximum output current available when the output terminal is not so grounded; (3) PSRR: Power supply rejection ratio: Change in input offset voltage to corresponding change in one of the power supply voltages ( $\pm V_{cc}$ ). Ideally, PSRR =  $\infty$ ; in practice, it is of the order of a few dBV.

#### FREQUENCY ROLL-OFF

It is the fall-off of the voltage gain at high frequencies. This is indicated by gain-bandwidth product. Roll-off to higher frequencies is achieved by frequency compensation.

#### INVERTING AMPLIFIER (VIRTUAL GROUND AMPLIFIER)

Fig. 3

- Output impedance with feedback is Output impedance of the OP-AMP of closed-loop gain (Open-loop gain).
- Node  $a$  is almost at ground potential.
- Closed-loop voltage gain  $V_{out}/V_{in} = -R_2/R_1$ .
- Input impedance =  $R_1$ .
- Output impedance =  $R_2$ .

#### NON-INVERTING AMPLIFIER

Fig. 4

- Non-inverting input.
- $A_v = 1 + \frac{R_2}{R_1}$
- $Z_{in} = R_1 \parallel R_2$
- $Z_{out} \rightarrow \text{Low}$

#### INTEGRATOR (LOW-PASS FILTER)

Fig. 5

- $R_2$  provides negative feedback for low-output impedance needs, but it also distorts the output.
- $V_{out} = -\left(\frac{1}{R_1 C}\right) \int V_{in} dt$

#### DIFFERENTIATOR (HIGH-PASS FILTER)

Fig. 6

- Inverse operation of the integrator circuit.

#### LEVEL CLAMPING

Fig. 7

- The output is clamped to  $Z_{out}$  voltage  $V_{ref}$ .

#### LINEAR VOLTAGE-TO-CURRENT CONVERTERS

Fig. 8

- Source Circuit
- Sink Circuit

#### LOGARITHMIC AMPLIFIER

Fig. 9

- Non-linear operation of BJT emitter diode.
- Reference Circuit

#### CHARGE AMPLIFIER

Fig. 10

- Operational amplifier.
- Non-linear operation.
- Non-linear operation.
- Non-linear operation.

#### PRECISION RECTIFIER & PEAK DETECTOR

Fig. 11

- Precision Rectifier
- Peak Detector

#### VOLTAGE FOLLOWER (UNITY GAIN AMPLIFIER)

Fig. 12

- Unity Gain Amplifier
- The output voltage "follows" the input voltage. Used as a buffer amplifier with high-input/low-output impedance capabilities.
- $Z_{in} = A \times [R_{in} \text{ Device}]$
- $Z_{out} = [R_{out} \text{ Device}] / A$

#### REGULATED POWER SUPPLY

Fig. 13

- The Zener diode offers a constant reference voltage ( $V_Z$ ) that is derived from the unregulated voltage ( $V_{in}$ ) via potential division by  $R_1$  and  $R_2$  and the Zener reference voltage, and compared by an inverting amplifier to provide a stable output voltage.
- $V_{out} = V_Z (1 + R_2/R_1)$  and  $V_{out} = V_Z (1 + R_2/R_1)$



## Synopsis

Part 2 of the fundamentals of electronic devices and basic electronic circuits.

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BarCharts are a great little reference. I would not recommend them as a study aid, but as a quick reference, they are great! I have used them for Chem, Physics, Electronics and Math. They are great for what they are.

It's legible, convenient, durable, water proof, etc.It's a handy little cheat sheet.I keep in a binder with the documents for a TI NSpire Calculator.I was kinda hoping that it would cover microwave transmission parameters. Some of that is on the Circuit Theory/Analysis card.Still, there was not much on the cards concerning practical impedance matching circuits. You just can't cram everything on a couple or three cards.All the basics are there.You should be able to derive the rest.

Nice to have on hand, well constructed gives a lot of useful information.

I was hoping there would be more to it but, its still a good referance

Excellent product. I strongly recommend this item.

High quality and delivered on time.

This is part 1 of 2. It Comes before part 2, and is the first in it's series. It's also laminated, which is great for eating Taco bell near.

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