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# Electronics 1 Part 2 (Quickstudy: Academic)

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**Quick Study ACADEMIC** **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.
- $A_{v1} = A_{v2} = A_{v(d)} = 1$ ,  $F_{max} = f_{max} = \infty$
- Gain-bandwidth (GBW)  $\rightarrow \infty$
- 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  $V_{os} = -I_{bias} \times (R_1 \times R_2/R_1)$  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 ( $\pm 1$  mV):** 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  $V_o$  is  $V_{os} = V_{os} = 0$  and this circuit can reject common-mode signals due to its common-mode gain ( $A_d = 0$ ). For differential mode signals  $V_{os} = \text{high}$  the gain ( $A_d = \infty$ ). The ratio  $A_d/A_c$ , common-mode rejection ratio (CMRR), in practical OP-AMPS,  $A_d = 0$  and  $A_c = \infty$ , 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  $\pm V_s$ ).
- 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  $\pm V_s$ .

**SLEW RATE:** Maximum rate at which the output voltage can change (involvement), in ideal OP-AMP,  $dV_o/dt \rightarrow \infty$ .

**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 ( $\pm V_s$ ). 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)  $\ll$  closed-loop gain.
- (Open-loop gain)
- Node  $a$  is almost at ground potential.
- Closed-loop voltage gain  $V_o/V_i = -R_2/R_1$
- 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.
- $V_o = -\frac{1}{R_1 C} \int V_i dt$

**DIFFERENTIATOR (HIGH-PASS FILTER)**

Fig. 6

- Inverse operation of the integrator circuit.
- $V_o = -R_2 C \frac{dV_i}{dt}$

**LEVEL CLAMPING**

Fig. 7

- The output is clamped to Zener voltage  $V_z$ .

**LINEAR VOLTAGE-TO-CURRENT CONVERTERS**

Fig. 8

- Source Circuit
- Sink Circuit

**LOGARITHMIC AMPLIFIER**

Fig. 9

- Non-inverting current of BJT emitter
- Reference Current
- $V_o = -V_T \ln \left( \frac{V_i}{I_{ref} R_1} \right)$

**CHARGE AMPLIFIER**

Fig. 10

- Capacitor
- Nonlinear operation
- Of the inverter
- $V_o = -\frac{1}{C} \int I_i dt$

**PRECISION RECTIFIER & PEAK DETECTOR**

Fig. 11

- Precision Rectifier
- Peak Detector

**VOLTAGE FOLLOWER (UNITY GAIN AMPLIFIER)**

Fig. 12

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

**REGULATED POWER SUPPLY**

Fig. 13

- The Zener diode offers a constant reference voltage ( $V_z$ ) that divides from the unregulated voltage ( $V_u$ ) 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.
- $V_o = V_z (1 + R_2/R_1)$  and  $V_o = V_z (1 + R_2/R_1)$



## Synopsis

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

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Stashed this away for reference on projects if anything is forgotten or disputed. No longer need internet if its not available. The quality is good, but the amount of information is overwhelming. If you are going to actually be studying for a class, I recommend making your own study card in addition to buying this as there are many benefits to doing so.

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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