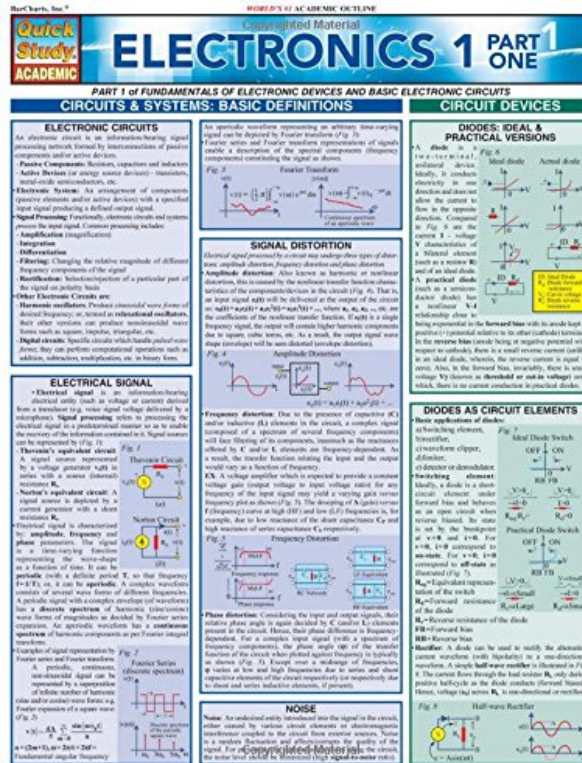


ELECTRONICS 1 PART 1 (QUICKSTUDY: ACADEMIC) BY INC. BARCHARTS



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PART 1 of FUNDAMENTALS OF ELECTRONIC DEVICES AND BASIC ELECTRONIC CIRCUITS

CIRCUITS & SYSTEMS: BASIC DEFINITIONS

ELECTRONIC CIRCUITS
An electronic circuit is an information-bearing signal processing network formed by interconnections of passive components and/or active devices.

- Passive Components:** Resistor, capacitor and inductor.
- Active Devices:** (or energy source devices) - transistors, metal-oxide-semiconductors, etc.

Electronic System: An arrangement of components (passive elements and/or active devices) with a specified input signal producing a defined output signal.

Signal Processing: Functionally, electronic circuits and systems process the input signal. Common processing includes:

- Amplification:** (magnification)
- Integration**
- Differentiation**
- Filtering:** Changing the relative magnitude of different frequency components of the signal.
- Rectification:** Selection/retention of a particular part of the signal on periodic basis.

Other Electronic Circuits are:

- Harmonic oscillators:** Produce sinusoidal wave forms of desired frequency, or, act as relaxation oscillators, their other versions can produce non-sinusoidal wave forms such as square, trapezoid, triangular, etc.
- Digital circuits:** Specific circuits which handle pulsed-wave flows; they can perform computational operations such as addition, subtraction, multiplication, etc. in binary form.

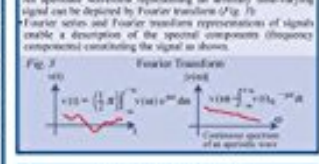
ELECTRICAL SIGNAL
Electrical signal is an information-bearing electrical entity (such as voltage or current) derived from a transducer (e.g. voice signal voltage delivered by a microphone). Signal processing refers to processing the electrical signal in a predetermined manner so as to enable the recovery of the information contained in it. Signal sources can be represented by (Fig. 1):

- Thévenin's equivalent circuit:** A signal source is represented by a voltage generator V_{th} in series with a source (internal) resistance R_{th} .
- Norton's equivalent circuit:** A signal source is depicted by a current generator with a shunt resistance R_{th} .

Electrical signal is characterized by amplitude, frequency and phase parameters. The signal is a time-varying function representing the wave-shape as a function of time. It can be periodic with a definite period T , so that frequency $f = 1/T$, or, it can be aperiodic. A complex waveform consists of several wave forms of different frequencies. A periodic signal with a complex envelope (of waveforms) has a discrete spectrum of harmonics (sinusoidal) wave forms of magnitudes as decided by Fourier series expansion. An aperiodic waveform has a continuous spectrum of harmonic components as per Fourier integral transforms.

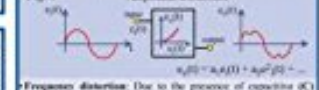
Examples of signal representation by Fourier series and Fourier transform:

- A periodic, continuous, non-sinusoidal signal can be represented by a superposition of infinite number of harmonic (sine and/or cosine) wave forms; e.g. Fourier expansion of a square wave (Fig. 2).
- Aperiodic waveform has a continuous spectrum of harmonic components as per Fourier integral transforms.



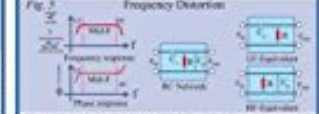
SIGNAL DISTORTION
Electrical signal processed by a circuit may undergo three types of distortion: amplitude distortion, frequency distortion and phase distortion.

Amplitude distortion: Also known as harmonic or nonlinear distortion, this is caused by the nonlinear transfer function characteristics of the components/devices in the circuit (Fig. 4). That is, an input signal $x(t)$ will be delivered at the output of the circuit as $y(t) = a_0x(t) + a_1x^2(t) + a_2x^3(t) + \dots$, where a_0, a_1, a_2, \dots are the coefficients of the nonlinear transfer function. If $x(t)$ is a single frequency signal, the output will contain higher harmonic components due to square, cubic terms, etc. As a result, the output signal wave shape (envelope) will be seen distorted (envelope distortion).



Frequency distortion: Due to the presence of capacitive (C) and/or inductive (L) elements in the circuit, a complex signal (composed of a spectrum of several frequency components) will face filtering of its components, inasmuch as the reactances offered by C and/or L elements are frequency-dependent. As a result, the transfer function relating the input and the output would vary as a function of frequency.

EX: A voltage amplifier which is expected to provide a constant voltage gain (output voltage to input voltage ratio) for any frequency of the input signal may yield a varying gain versus frequency plot as shown (Fig. 3). The drooping of $A_{voltage}$ versus f (frequency) curve at high (HF) and low (LF) frequencies is, for example, due to low reactance of the shunt capacitance C_p and high reactance of series capacitance C_s respectively.



Phase distortion: Considering the input and output signals, their relative phase angle is again decided by C (and/or L) elements present in the circuit. Hence, their phase difference is frequency-dependent. For a complex input signal (with a spectrum of frequency components), the phase angle $\phi(t)$ of the transfer function of the circuit when plotted against frequency is typically as shown (Fig. 3). Except over a midrange of frequencies, ϕ varies at low and high frequencies due to series and shunt capacitive elements of the circuit respectively (or inductively due to shunt and series inductive elements, if present).

NOISE
Noise: An undesired entity introduced into the signal in the circuit, either caused by various circuit elements or electromagnetic interference coupled to the circuit from exterior sources. Noise is a random fluctuation and affects/compromises the quality of the signal. For noise level (level) to be determined (high signal-to-noise ratio),

CIRCUIT DEVICES

DIODES: IDEAL & PRACTICAL VERSIONS

A diode is a two-terminal, unilateral device. Ideally, it conducts electricity in one direction and does not allow the current to flow in the opposite direction. Compared to Fig. 5, the current I - voltage V characteristics of a bilateral element (such as a resistor R) and of an ideal diode.

A practical diode (such as a semiconductor diode) has a nonlinear $V-I$ relationship close to being exponential in the forward bias with its anode kept at positive (+) potential relative to its other (cathode) terminal. In the reverse bias (anode being at negative potential with respect to cathode), there is a small reverse current (analogous to an ideal diode, wherein, the reverse current is equal to zero). Also, in the forward bias, invariably, there is small voltage V_f (known as threshold or cut-in voltage) until which, there is no current conduction in practical diodes.

DIODES AS CIRCUIT ELEMENTS

Basic applications of diodes:

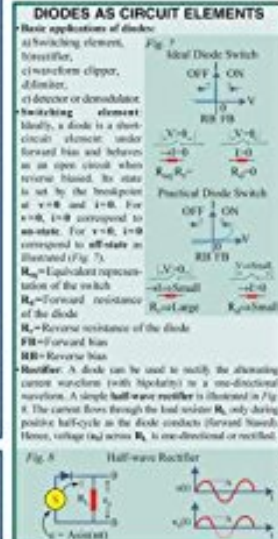
- (a) switching element.
- (b) waveform clipper.
- (c) limiter.
- (d) detector or demodulator.

switching element: Ideally, a diode is a short-circuit element under forward bias and behaves as an open circuit when reverse biased. Its state is set by the breakpoint at $v = 0$ and $i = 0$. For $v > 0$, $i > 0$ correspond to on-state. For $v < 0$, $i < 0$ correspond to off-state as illustrated (Fig. 7).

R_{on} = Equivalent representation of the switch
 $R_{on} = 0$ (Small) $R_{on} = \infty$ (Large)
 R_{off} = Forward resistance of the diode
 $R_{off} = \infty$ (Large) $R_{off} = 0$ (Small)

FB = Forward bias
RB = Reverse bias

Rectifier: A diode can be used to rectify the alternating current waveform (with periodicity) to a unidirectional waveform. A simple half-wave rectifier is illustrated in Fig. 8. The current flows through the load resistor R_L only during positive half-cycle as the diode conducts (forward biased). Hence, voltage (across R_L) is one-directional or rectified.



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- Published on: 2001-03-01
- Released on: 2001-03-01
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