Facoltà di Ingegneria
Università degli Studi di Firenze
Dipartimento di Elettronica e Telecomunicazioni

Fondamenti degli strumenti di misura

Ing. Andrea Zanobini
Dipartimento di Elettronica e Telecomunicazioni

Polarità, legge di Ohm, tensione alternata

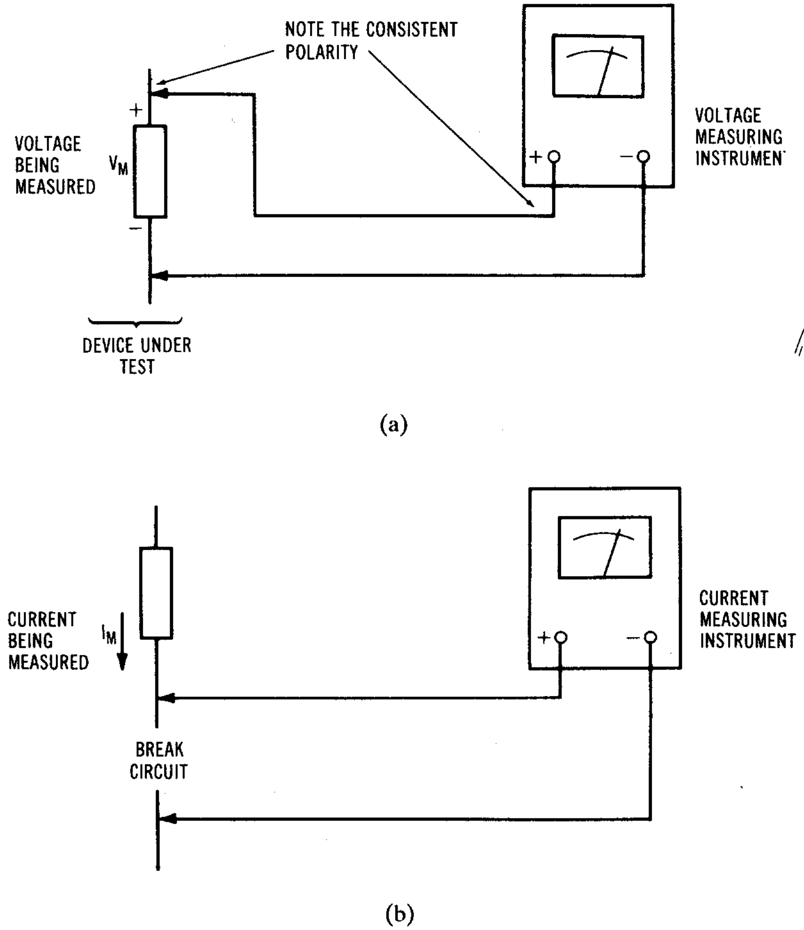


Figure 1-3 (a) Voltage measurements are made at two points. Note that the polarity of the measuring instrument is consistent with the polarity of the voltage being measured. (b) Current measurements are made by inserting the measuring instrument into the circuit so that the current flows through the instrument.

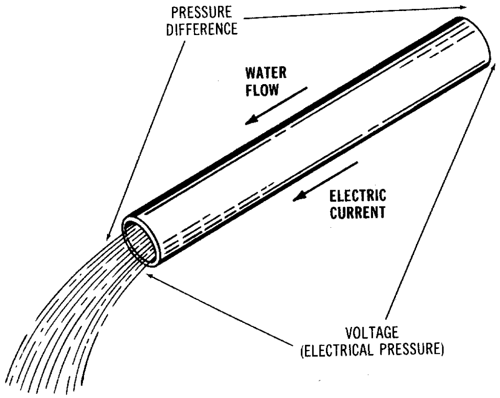


Figure 1 The water pipe analogy shows how water flow and pressure difference behave similarly to electrical current and voltage.

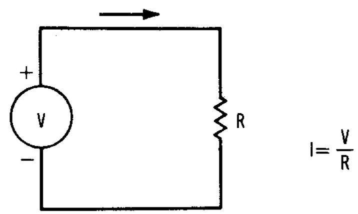


Figure 1-4 Ohm's law is used to compute the amount of current (I) that will result with voltage (V) and resistance (R).

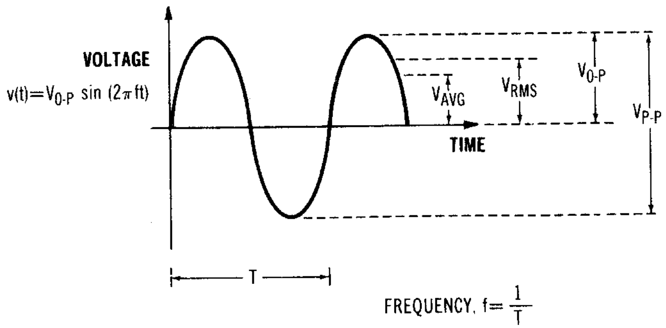


Figure 1-6 The most common form of alternating current is the sine wave. The voltage of the waveform can be described by the RMS value, zero-to-peak value, or the peak-to-peak value.

Tensione alternata, valore efficace, valor medio

$$v(t) = V_{OP} \sin(2\pi f t + \varphi) = V_{OP} \sin(\omega t + \varphi)$$

$$V_{RMS} = \sqrt{\frac{1}{T}\int_{t_0}^{t_0+T} v^2(t)\, dt} \overset{*}{=} \frac{1}{\sqrt{2}} V_{OP} \overset{*}{=} 0.707\, V_{OP}$$

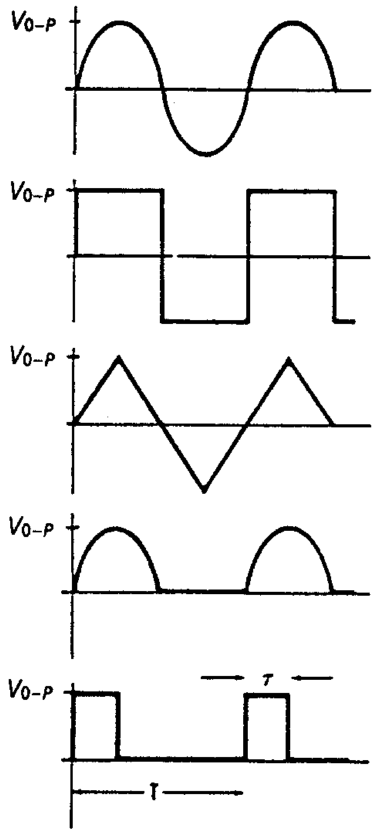
$$V_{AVG} = \frac{1}{T}\int_{t_0}^{t_0+T} \left|v(t)\right| dt \overset{*}{=} \frac{2}{\pi} V_{OP} \overset{*}{=} 0.637\, V_{OP}$$

$$\begin{cases} V_{RMS} = 10V \\ V_{DC} = 10V \end{cases} \Rightarrow \quad R = 5\,\Omega \quad \Rightarrow \quad P = 20\ W$$

Forme d'onda non sinusoidali

$$\begin{cases} FC = \text{Fattore di cresta} = V_{OP} / V_{RMS} \\ FF = \text{Fattore di forma} = V_{RMS} / V_{AVG} \end{cases}$$

Fig. 6 TABLE OF WAVEFORMS WITH PEAK-TO-PEAK VOLTAGE (V_{P-P}), RMS VOLTAGE (V_{RMS}), ZERO-TO-PEAK VOLTAGE (V_{0-P}), AND CREST FACTOR FOR EACH WAVEFORM. V_{AVG} IS THE FULL-WAVE RECTIFIED AVERAGE VALUE OF THE WAVEFORM.



Waveform	V_{P-P}	V_{RMS}	V_{AVG}	Crest Factor
SINE WAVE	$2\ V_{0-P}$	$\frac{1}{\sqrt{2}} V_{0-P}$ or $0.707\ V_{0-P}$	$\frac{2}{\pi} V_{0-P}$ or $0.637\ V_{0-P}$	$\sqrt{2}$ or 1.414
SQUARE WAVE	$2\ V_{0-P}$	V_{0-P}	V_{0-P}	1
TRIANGLE WAVE	$2\ V_{0-P}$	$\frac{1}{\sqrt{3}} V_{0-P}$ or $0.577\ V_{0-P}$	$\frac{1}{2} V_{0-P}$	$\sqrt{3}$ or 1.732
HALF SINE WAVE	V_{0-P}	$\frac{1}{2} V_{0-P}$	$\frac{1}{\pi} V_{0-P}$ or $0.318\ V_{0-P}$	2
PULSE TRAIN	V_{0-P}	$\sqrt{\frac{\tau}{T}}\ V_{0-P}$	$\frac{\tau}{T} V_{0-P}$	$\sqrt{\frac{T}{t}}$

Armoniche – Onda quadra

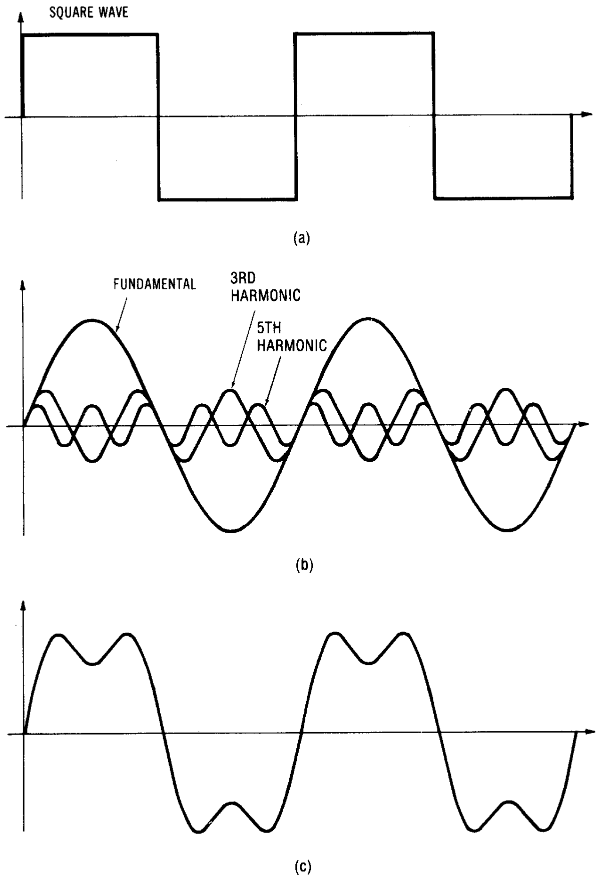


Figure 1-9 The square wave can be broken up into an infinite number of odd harmonics. The more harmonics that are included, the more the waveform approximates a square wave. (a) The original square wave. (b) The fundamental, 3rd harmonic, and 5th harmonic. (c) The fundamental plus 3rd harmonic. (d) The fundamental plus the 3rd and 5th harmonics. (e) The fundamental plus the 3rd, 5th, and 7th harmonics. (f) The fundamental plus the 3rd, 5th, 7th, and 9th harmonics.

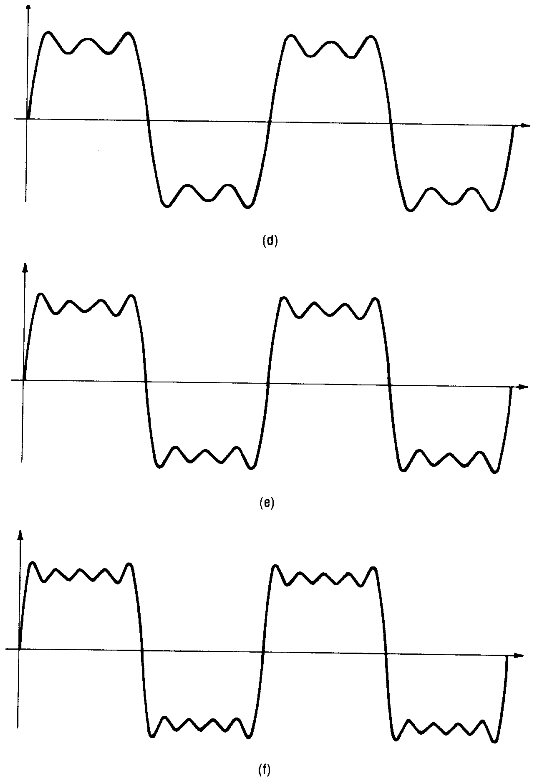


Figure 1-9 *(Continued)*

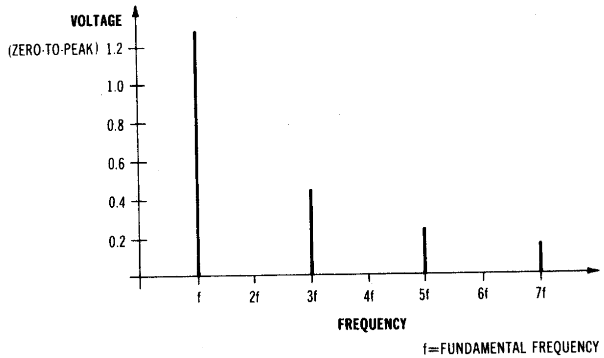


Figure 1-10 The frequency domain representation of a square wave, shown out to the 7th harmonic.

Treno di impulsi – Tavola delle armoniche
Combinare tensioni continue e alternate

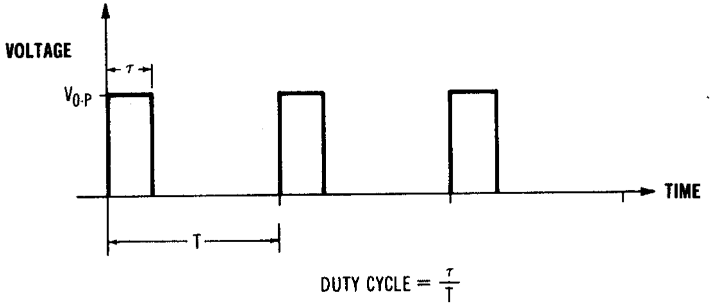


Figure 1-11 The pulse train is a common waveform in digital systems. The duty cycle describes the percentage of time that the waveform is at the higher voltage.

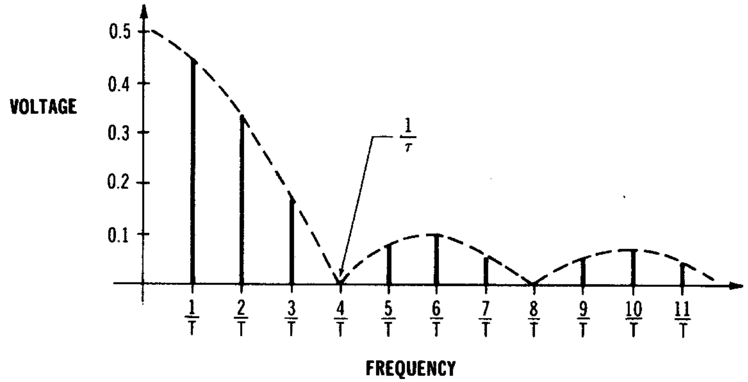


Figure 1-12 The frequency domain plot for a pulse train with a 25 percent duty cycle. [illegible]pe of the harmonics falls to zero when the frequency equals 1/τ.

Fig. 11 TABLE OF HARMONICS FOR A VARIETY OF WAVEFORMS. ALL WAVEFORMS HAVE A ZERO-TO-PEAK VALUE OF 1. THE NUMBER OF SIGNIFICANT HARMONICS COLUMN LISTS THE HIGHEST HARMONIC WHOSE AMPLITUDE IS AT LEAST 10 PERCENT OF THE FUNDAMENTAL.

Waveform	Fund	2nd	Harmonics 3rd	4th	5th	6th	7th	Sig Harm (10%)	Equation
Sine wave	1.000	0.000	0.000	0.000	0.000	0.000	0.000	1	
Square	1.273	0.000	0.424	0.000	0.255	0.000	0.182	9	$\frac{4}{n\pi}$ for odd n
Triangle	0.811	0.000	0.090	0.000	0.032	0.000	0.017	3	$\frac{8}{n^2\pi^2}$ for odd n
Pulse (50% duty cycle)	0.637	0.000	0.212	0.000	0.127	0.000	0.091	9	$\frac{2}{n\pi}\sin\left(\frac{n\pi}{2}\right)$
Pulse (25% duty cycle)	0.450	0.318	0.150	0.000	0.090	0.105	0.064	14	$\frac{2}{n\pi}\sin\left(\frac{n\pi}{4}\right)$
Pulse (10% duty cycle)	0.197	0.187	0.172	0.151	0.127	0.101	0.074	26	$\frac{2}{n\pi}\sin\left(\frac{n\pi}{10}\right)$

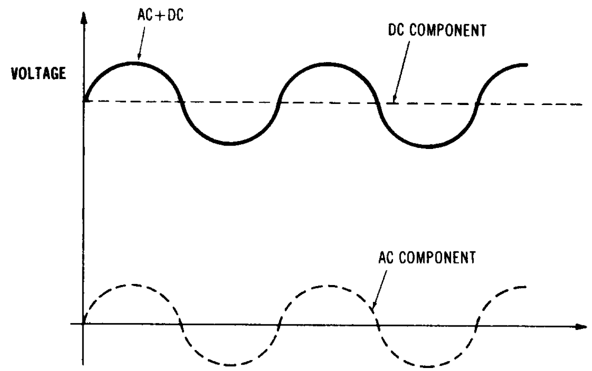
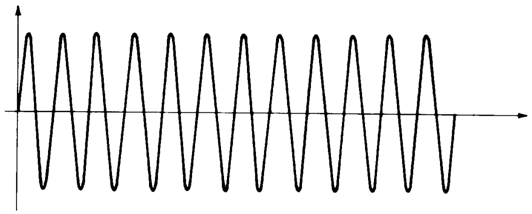
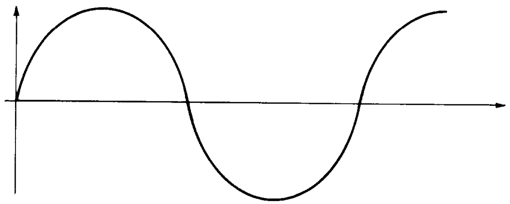


Figure 1-13 The waveform shown can be broken down into a DC component and an AC component. The DC component is just the average value of the original waveform.

Segnali modulati

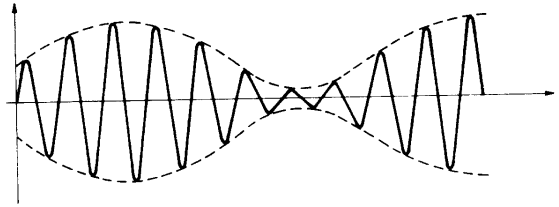


(A) The original carrier.

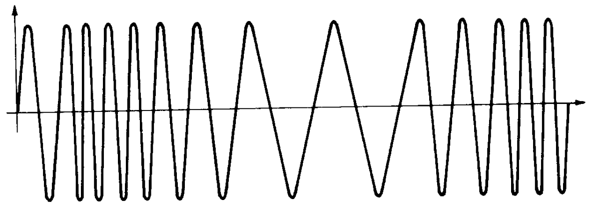


(B) The modulating signal.

Figure 1-16 Amplitude and frequency modulation. (a) The original carrier. (b) The modulating signal. (c) The resulting signal if amplitude modulation is used. (d) The resulting signal if frequency modulation is used.

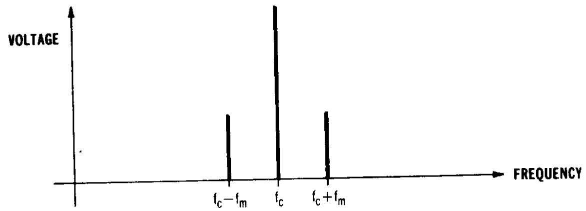


(C) The resulting signal if amplitude modulation is used.

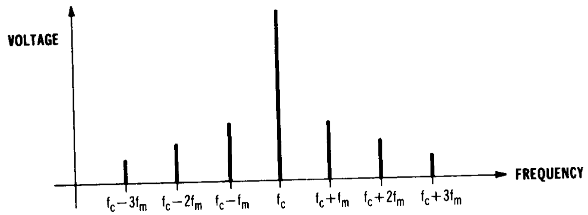


(D) The resulting signal if frequency modulation is used.

gure 1-16 *(Continued)*



(C) An AM carrier (with single sine wave modulation) has a single pair of sidebands.



(D) An FM carrier (with single sine wave modulation) may have many pairs of sidebands.

Figure 1-17 *(Continued)*

DECIBEL

$$dB = 10\ Log\left(\frac{P_2}{P_1}\right) \stackrel{*}{=} 10\ Log\left(\frac{V_2^2/R_2}{V_1^2/R_1}\right) \stackrel{*}{=} 10\ Log\left(\frac{V_2^2}{V_1^2}\right) = 20\ Log\left(\frac{V_2}{V_1}\right)$$

$$\left(\frac{P_2}{P_1}\right) = 10^{dB/10}\ ; \quad \left(\frac{V_2}{V_1}\right) = 10^{dB/20}$$

- Compressione della scala di misura, infatti un range di potenze (1❍W:100W) vale 80dB.
- Guadagni e le perdite dovute ad attenuatori, filtri, amplificatori possono essere sommati tra loro, se espressi in dB.

Tra l'altro avremo che:

- 0 dB corrispondono ad un rapporto unitario e cioè ingresso uguale uscita.
- 3 dB corrispondono ad un rapporto che per le potenze vale 2. Un livello di potenza che cambia in + o -3 dB raddoppia o dimezza il valore originario.
- 6 dB corrispondono ad un rapporto che per le tensioni vale 2. Un livello di tensione che cambia in + o -6 dB raddoppia o dimezza il valore originario.
- 10 dB corrispondono ad un rapporto che per le potenze vale 10. Solo in questo caso il rapporto non cambia i valori.

DECIBEL ASSOLUTI – TAVOLE (1)

Fig. 16 SUMMARY OF EQUATIONS RELATING TO DECIBEL CALCULATIONS. VOLTAGES (V) ARE RMS VOLTAGE, AND POWER (P) IS IN WATTS.

$$\mathrm{dB} = 10 \log\left(\frac{P_2}{P_1}\right)$$

$$\mathrm{dB} = 20 \log\left(\frac{V_2}{V_1}\right)$$

$$\mathrm{dBm} = 10 \log\left(\frac{P}{0.001}\right)$$

$$\mathrm{dBV} = 20 \log(V)$$

$$\mathrm{dBm}\ (50\ \Omega) = 20 \log\left(\frac{V}{0.224}\right)$$

$$\mathrm{dBm}\ (75\ \Omega) = 20 \log\left(\frac{V}{0.274}\right)$$

$$\mathrm{dBm}\ (600\ \Omega) = 20 \log\left(\frac{V}{0.775}\right)$$

$$\mathrm{dBW} = 10 \log(P)$$

$$\mathrm{dBf} = 10 \log\left(\frac{P}{1 \times 10^{-15}}\right)$$

$$\mathrm{dB\mu V} = 20 \log\left(\frac{V}{1 \times 10^{-6}}\right)$$

$$\mathrm{dBc} = 10 \log\left(\frac{P}{P_{CARRIER}}\right)$$

$$\mathrm{dBc} = 20 \log\left(\frac{V}{V_{CARRIER}}\right)$$

Fig. 16 TABLE OF DECIBEL VALUES FOR VOLTAGE RATIOS AND POWER RATIOS.

Decibels	Power Ratio	Voltage Ratio
100	10,000,000,000	100,000
90	1,000,000,000	31,623
80	100,000,000	10,000
70	10,000,000	3,162
60	1,000,000	1,000
50	100,000	316.2
40	10,000	100.0
30	1,000	31.62
20	100	10.00
10	10	3.162
0	1	1.000
−10	0.1	0.3162
−20	0.01	0.1000
−30	0.001	0.03162
−40	0.0001	0.01000
−50	0.00001	0.003162
−60	0.000001	0.001000
−70	0.0000001	0.0003162
−80	0.00000001	0.0001000
−90	0.000000001	0.00003162
−100	0.0000000001	0.00001000

Decibels	Power Ratio	Voltage Ratio
10	10.0000	3.1623
9	7.9433	2.8184
8	6.3096	2.5119
7	5.0119	2.2387
6	3.9811	1.9953
5	3.1623	1.7783
4	2.5119	1.5849

DECIBEL ASSOLUTI – TAVOLE (2)

Fig. 16 *(Continued)*

Decibels	Power Ratio	Voltage Ratio
3	1.9953	1.4125
2	1.5849	1.2589
1	1.2589	1.1220
0.9	1.2303	1.1092
0.8	1.2023	1.0965
0.7	1.1749	1.8039
0.6	1.1482	1.0715
0.5	1.1220	1.0593
0.4	1.0965	1.0471
0.3	1.0715	1.0351
0.2	1.0471	1.0233
0.1	1.0233	1.0116
0	1.0000	1.0000
−0.1	0.9772	0.9886
−0.2	0.9550	0.9772
−0.3	0.9333	0.9661
−0.4	0.9120	0.9550
−0.5	0.8913	0.9441
−0.6	0.8710	0.9333
−0.7	0.8511	0.9226
−0.8	0.8318	0.9120
−0.9	0.8128	0.9016
−1	0.7943	0.8913
−2	0.6310	0.7943
−3	0.5012	0.7079
−4	0.3981	0.6310
−5	0.3162	0.5623
−6	0.2512	0.5012
−7	0.1995	0.4467
−8	0.1585	0.3981
−9	0.1259	0.3548
−10	0.1000	0.3162

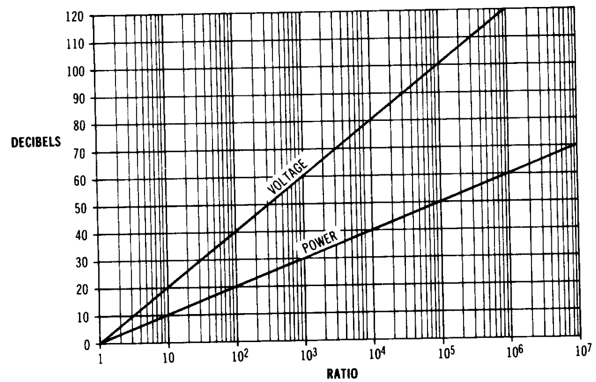


Figure 17 Graph for converting ratios to and from decibels for both voltage and power. Because of the logarithmic relationships, the plots are straight lines on log axes.

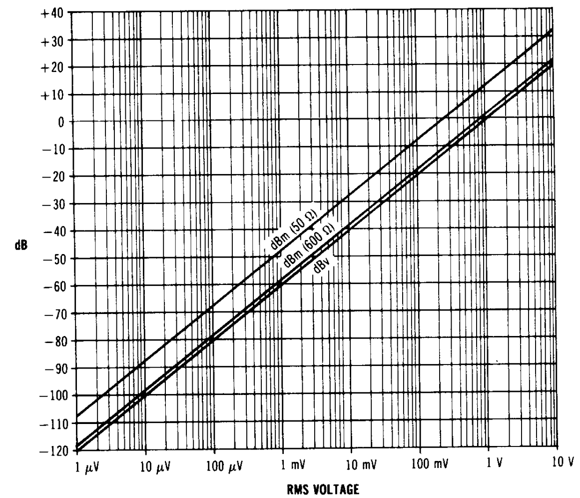


Figure 17 Graph of decibels versus voltage for dBV, dBm (50 Ω), and dBm (600Ω).

EFFETTO DI CARICO

Massimo trasferimento di tensione e potenza

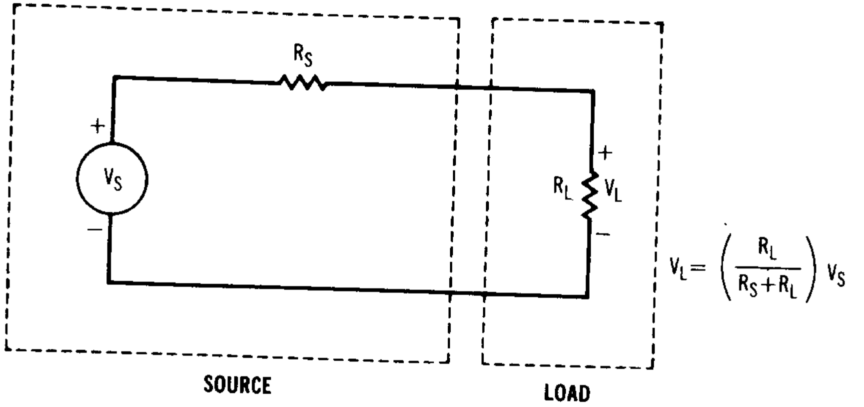
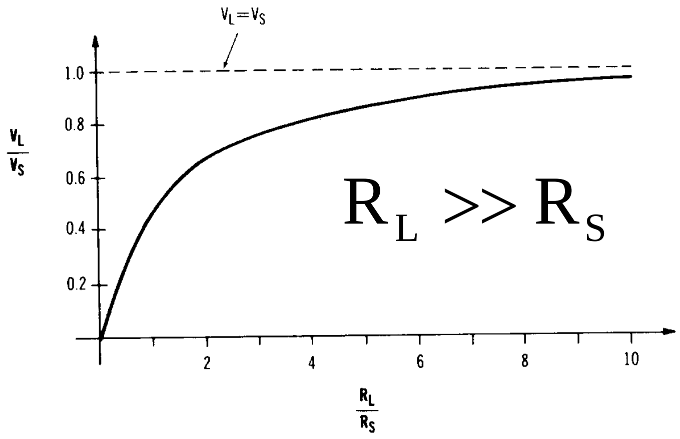


Figure 18 The source and load are connected together. The voltage across the load is given by the voltage divider equation. The loading effect causes this voltage to be less than the open-circuit voltage of the source.



$$R_L >> R_S$$

Figure 19 A plot of the output voltage due to the loading effect, as a function of the load resistance divided by the source resistance. The larger the load resistance, the better the voltage transfer.

$$R_L << R_S \Rightarrow V_L \approx 0$$

$$R_L >> R_S \Rightarrow V_L \approx V_S$$

In generale si ha solo il controllo di R_L

$$R_L = R_S$$

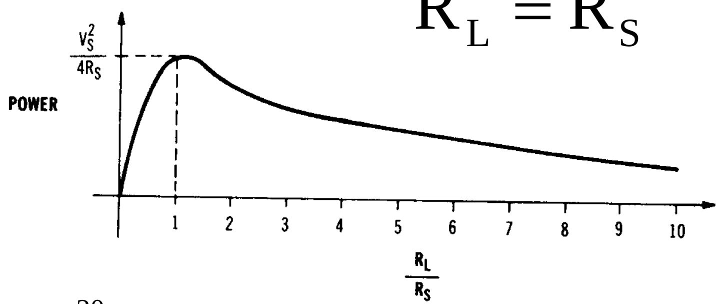


Figure 20 Plot of output power as a function of the load resistance divided by the source resistance. The output power is maximum when the two resistances are equal.

AMPIEZZA DI BANDA
FAMIGLIE LOGICHE

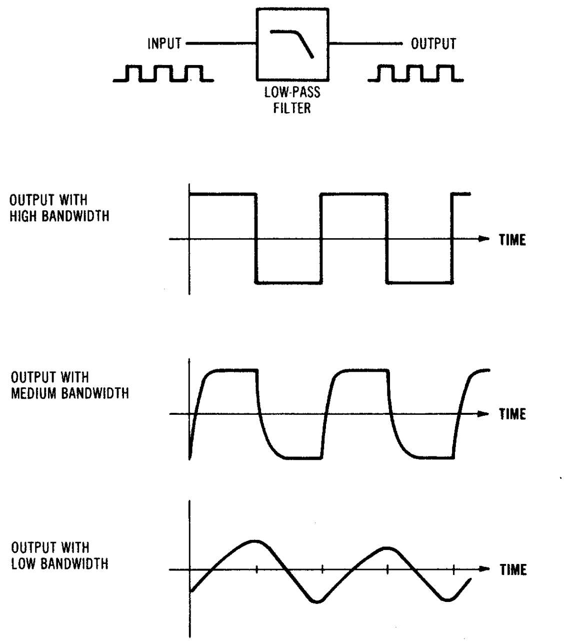


Figure 23 The effect of bandwidth on a square wave. With a very wide bandwidth, the square wave is undistorted; with a low bandwidth, the square wave is distorted.

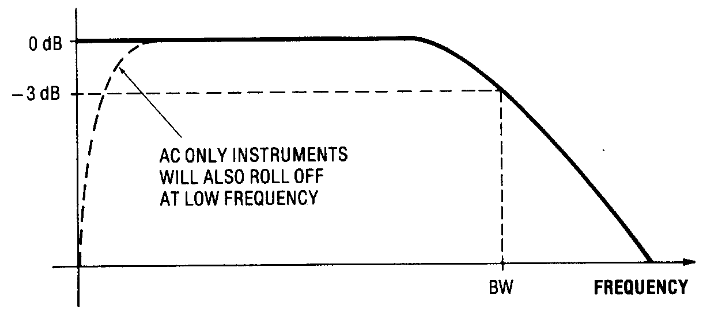
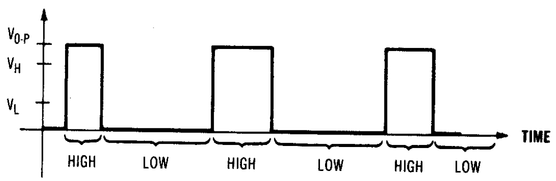
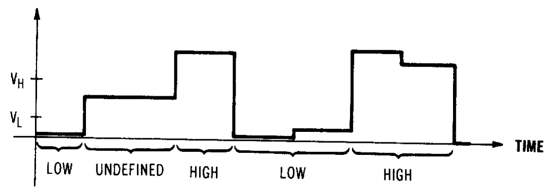


Figure 22 The frequency response of a typical measuring instrument rolls off at high frequencies. Some instruments that do not measure DC also roll off at low frequencies.



(A) A well behaved digital signal which is always a valid logic level.



(B) A digital signal that is undefined at one point.

Figure 24 Two digital signals.

Fig.25 LOGIC THRESHOLDS FOR THE MOST COMMON DIGITAL LOGIC FAMILIES. THE VALUES MAY VARY SLIGHTLY WITH DIFFERENT TYPES OF PARTS WITHIN THE SAME GENERAL FAMILY. ALL VALUES ARE IN VOLTS.

		Input Threshold		Output Guaranteed		Output Typical	
Logic Family	Supply Voltage	Low	High	Low	High	Low	High
TTL	5	0.8	2.0	0.4	2.4	0.2	3.5
CMOS	5	1.5	3.5	0.05	4.95	0	5.0
CMOS	10	3.0	7.0	0.05	9.95	0	10.0
CMOS	15	4.0	11.0	0.05	14.95	0	15.0
ECL	−5.2	−1.475	−1.105	−1.630	−0.980	−1.75	−0.90
ECL	5	3.525	3.895	3.370	4.020	3.25	4.10

TTL = Transistor Transistor Logic
CMOS = Complementary Metal Oxide Semiconductor
ECL = Emitter Coupled Logic