

Topic 6

Electrical Signals

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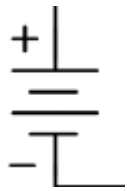


Electronic Logbook

- ◆ You must keep a **logbook** because:
 - It is a professional practice.
 - It helps you to learn; forces you to think and to reflect.
 - It is useful for your future reference.
- ◆ Here are some guidelines on using the logbook:
 - Logbook should include sketches, your thoughts etc., and does not need to be tidy. It definitely should not be “beautiful”.
 - Never copy someone else’s logbook – it is both cheating and useless to you.
 - Attach photo’s, plots, calculations, codes or anything else interesting in your logbook.
 - At the Oral Assessment in the last week of term, you will be asked to show the examiner your logbook and asked questions where answers are only be found in it.
- ◆ Electronic Logbook
 - MS Word or similar – simple, no learning required, sequential only
 - MS OneNote – Easy to learn, has hierarchy: book, section, pages
 - Github – Combines logbook with version control; probably more suitable for software lab than hardware lab.

Electrical signals – DC vs AC

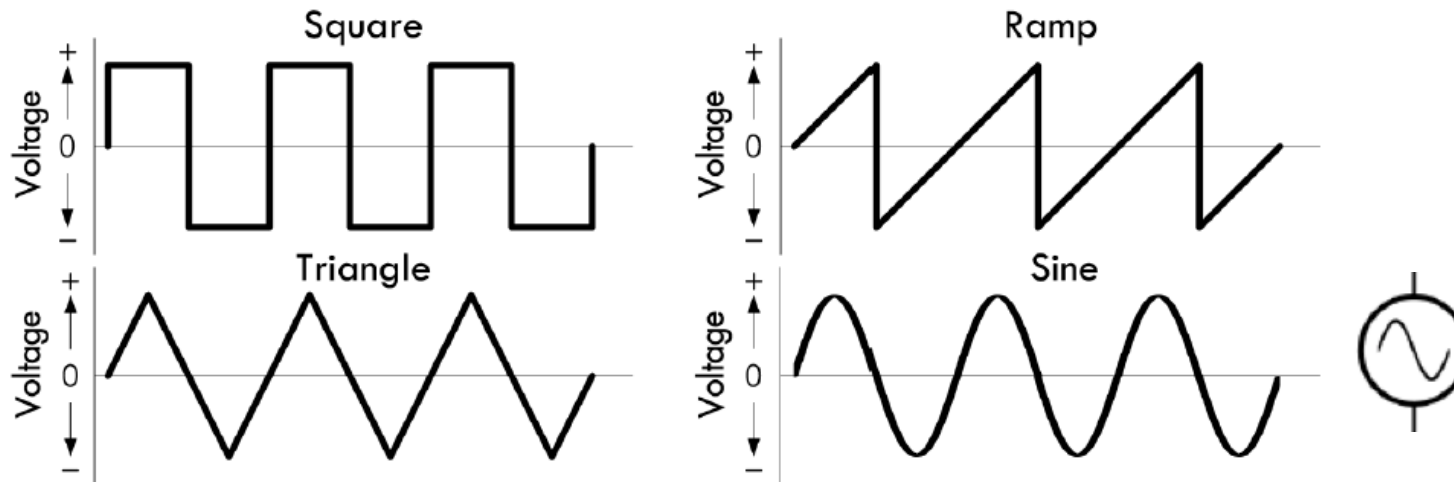
- ◆ Electrical voltage or current can be constant over time (at least over a reasonably long period of time) or vary over time.
- ◆ There are various types of electrical signals (voltage or current):



1. **Constant or dc/DC** - For example, the output voltage of a fully charged battery is substantially constant. Connecting a resistor across the battery will also result in a constant current flowing from the battery to the resistor. We call this dc voltage or current (i.e. **direct current**).

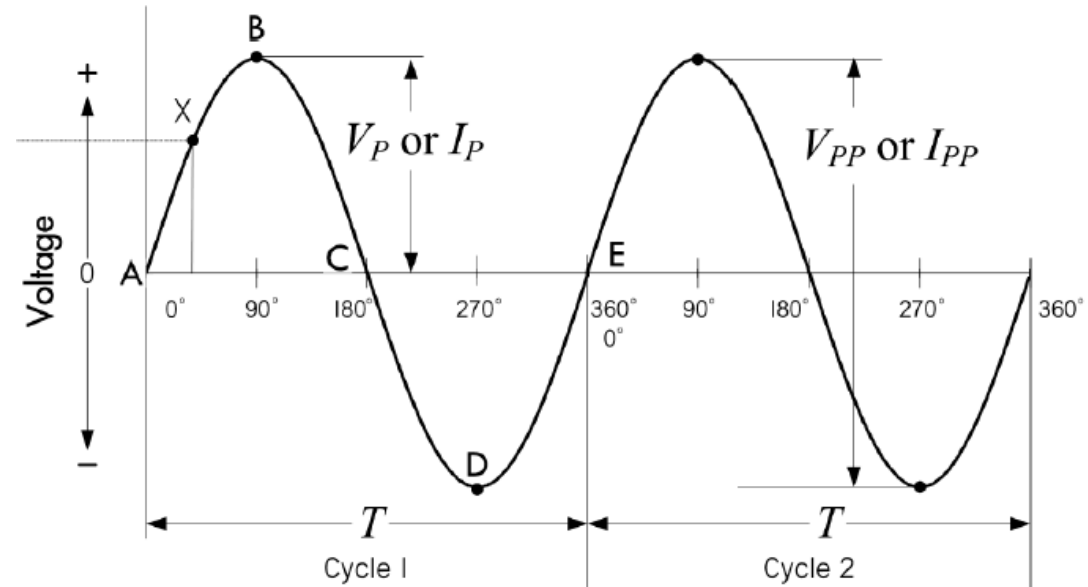
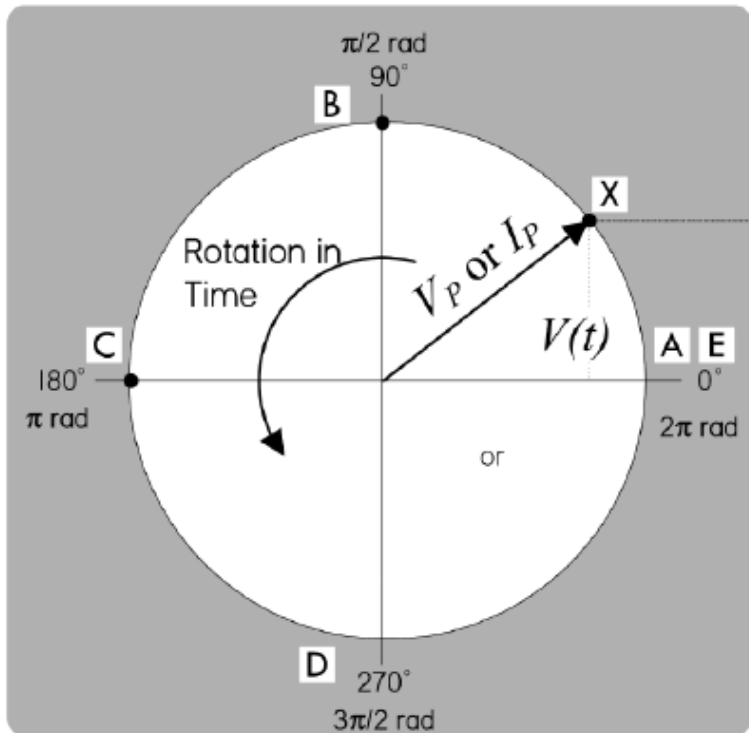
$$V = k, \text{ where } k \text{ is a constant.}$$

2. **Alternating Current or ac/AC** - Voltage from the mains supply is changing over time, and it alternates between positive and negative value following a sinusoidal function. We call this ac voltage (i.e. **alternating current**).



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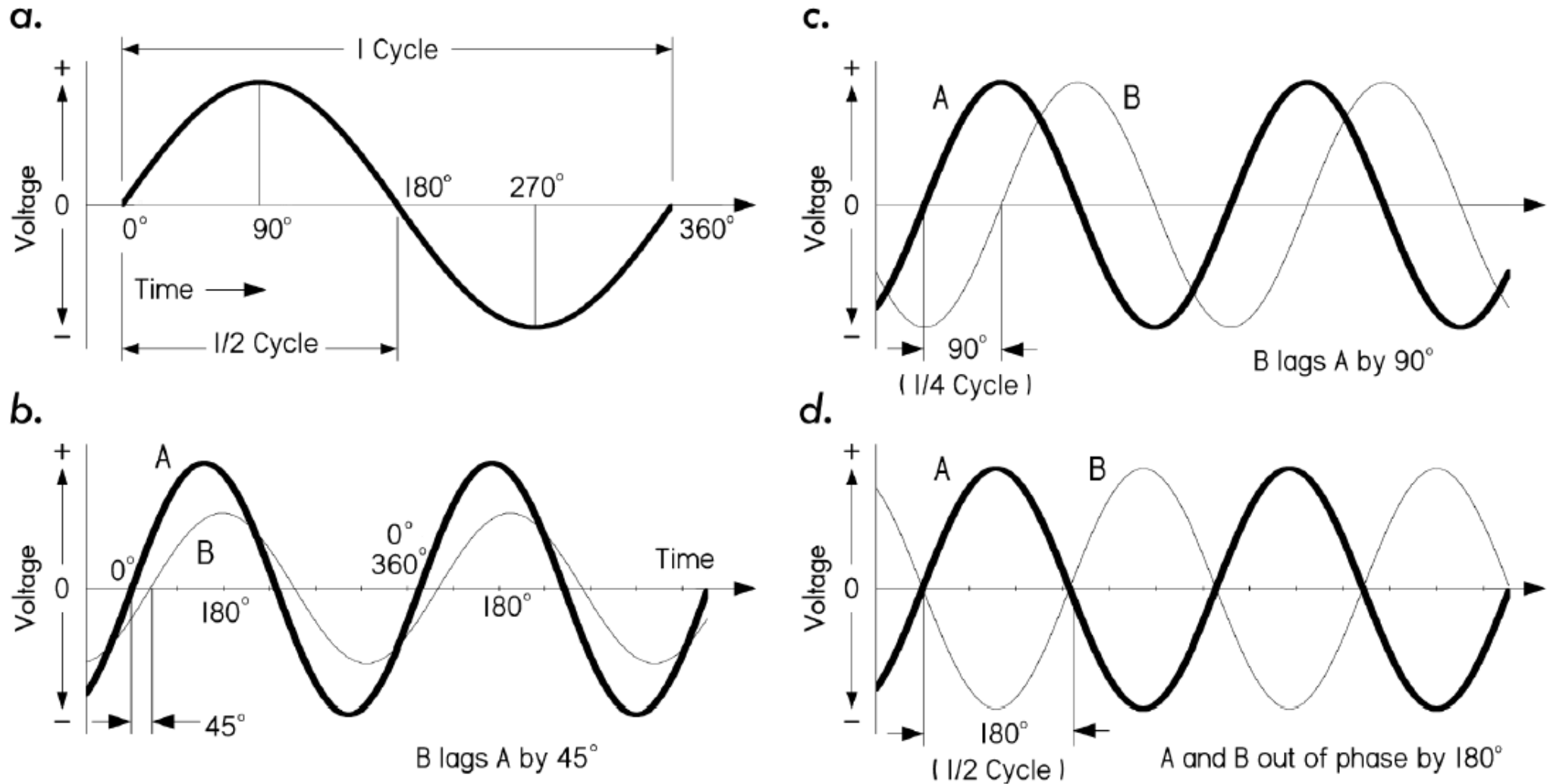
AC signal – mathematical representation



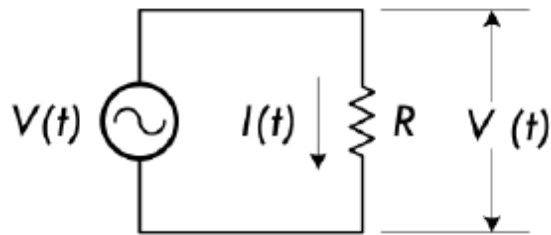
$$V(t) = V_P \sin (2\pi f t + 0^\circ) \quad f = 1 / T$$

- ◆ A sinewave is characterized by its:
 1. Amplitude V_p (or I_p for current)
 2. Frequency f in Hz (or ω in rad/sec) – remember: $\omega = 2\pi f$
 3. Phase Φ

AC signal – relative phases in sine waves



AC signal power – RMS voltage



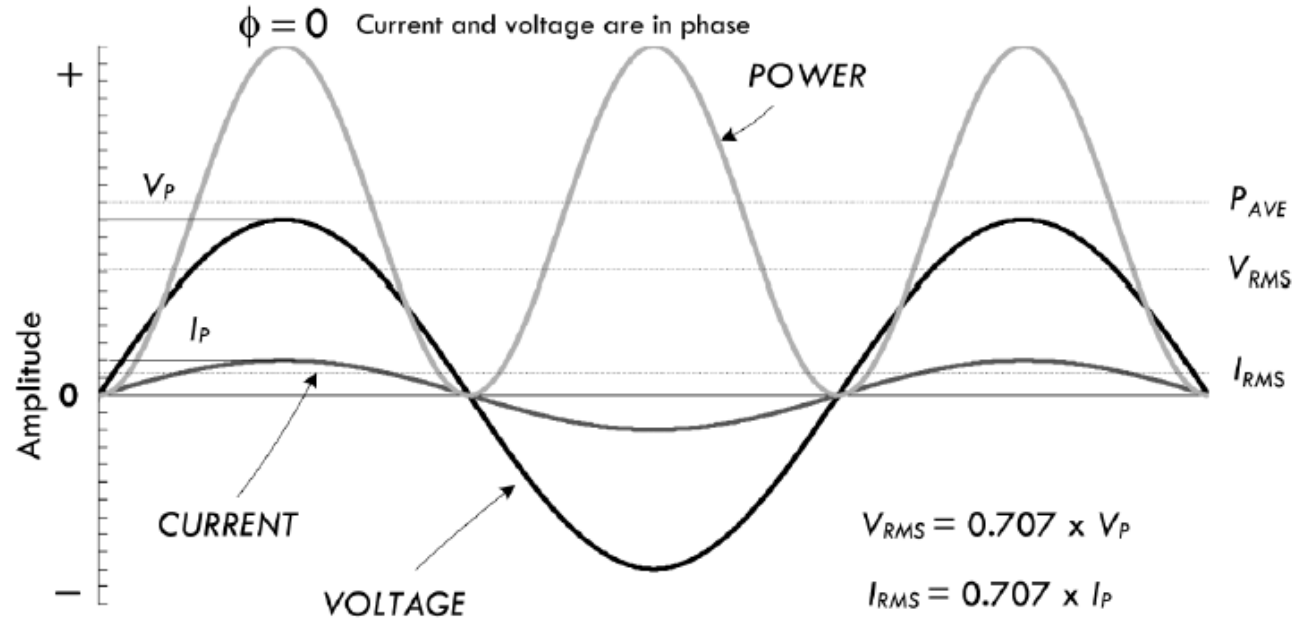
$$V(t) = V_P \sin(2\pi \times f \times t)$$

- ◆ According to Ohm's Law,

$$I(t) = \frac{V(t)}{R} = \frac{V_P}{R} \sin(2\pi \times f \times t)$$

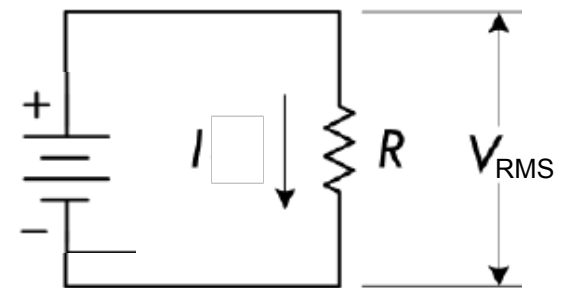
- ◆ Since Power = V x I

$$P(t) = \frac{V(t)^2}{R} = \frac{V_P^2}{R} \sin^2(2\pi ft)$$



Root Mean Square (RMS) value of an ac voltage (or current) is defined as the equivalent dc voltage (or current) that dissipates the same power in a give resistor.

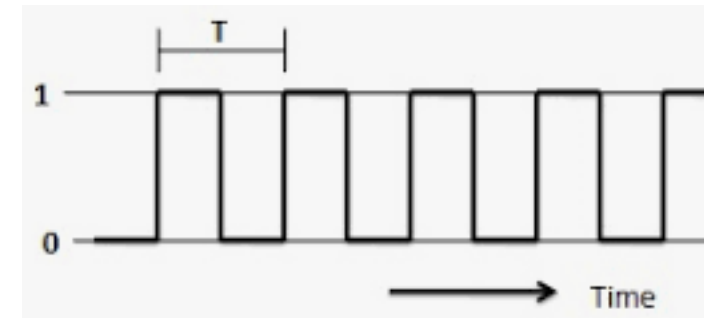
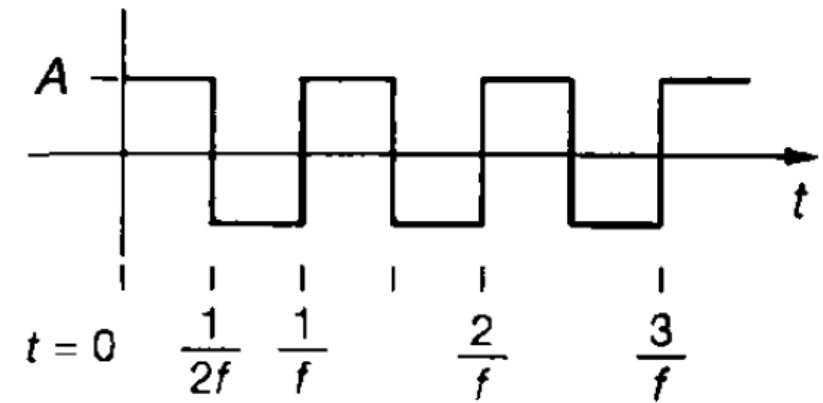
$$V_{RMS} = \sqrt{\frac{1}{T} \int_0^T V(t)^2 dt} = \frac{1}{\sqrt{2}} \times V_P = 0.707 \times V_P$$



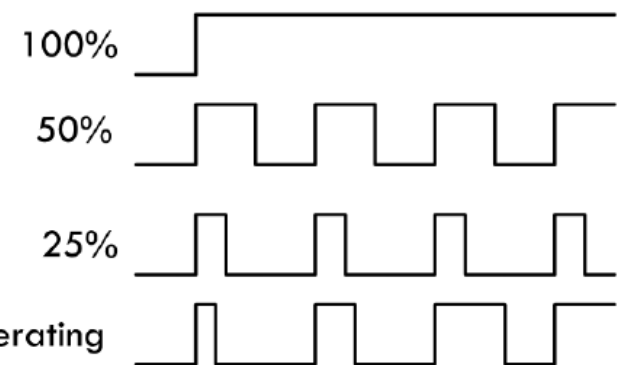
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Square wave, digital and PWM signals

- ◆ A square wave signal is symmetrical around 0 and have equal period at +A and -A.
- ◆ A digital signal is similar to square wave, but it only goes between 0 and +A. For example, for the ESP32 microcontroller, +A = 3.3V.
- ◆ A special type of digital pulse signal is known as a symmetric **clock signal** where the time spent in +A and in 0 are the same – e.g. the clock signal used in most microprocessors.
- ◆ In general, the duration spent on +A (mark period) and 0 (space period) may be different. This ratio mark:space (mark/space ratio) may also be expresses as **duty cycle** in percentage.
- ◆ Duty cycle = (mark period/total period) x 100%.
- ◆ A digital signal with varying duty cycle is also known as **Pulse Width Modulation (PWM)** signal.



Duty Cycle



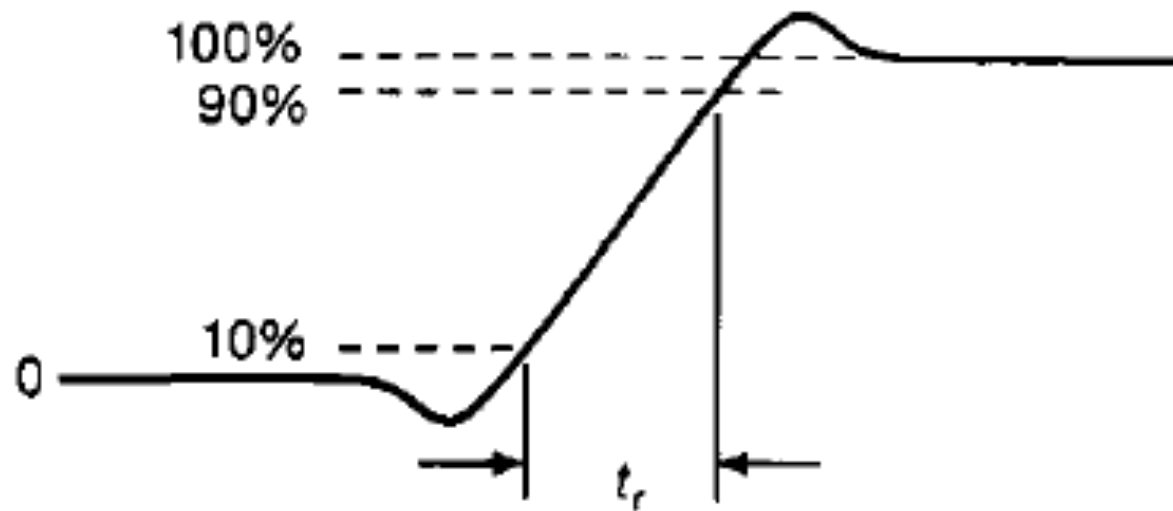
Noise signal

- ◆ Noise signal – general this is the signal voltage or current that you DON'T want, but it is there anyway. The noise signal can be random (such as noise signal from space), or predictable (e.g. noise caused by picking up the electrical mains at 50Hz).



Step signal

- ◆ **Step signal** – this is a theoretical signal where a signal goes from P to Q instantaneously. The step can be positive ($Q > P$) or negative ($P > Q$). In practice, the signal will take finite time to transit. Rise (fall) time t_r is defined as the time when a step signal rises (falls) from 10% to 90% of the final level.



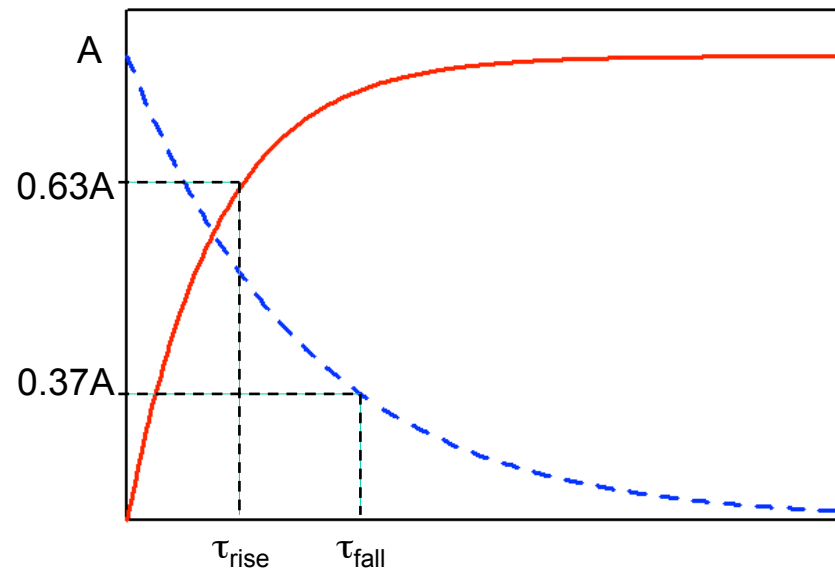
Exponential signals

- ◆ **Exponential signal** – This is often the output signal of a circuit driven by a step signal at the input. The mathematical representation of this signal is:

$$V = A (1 - e^{-t/\tau}) \quad \text{for rising exponential}$$

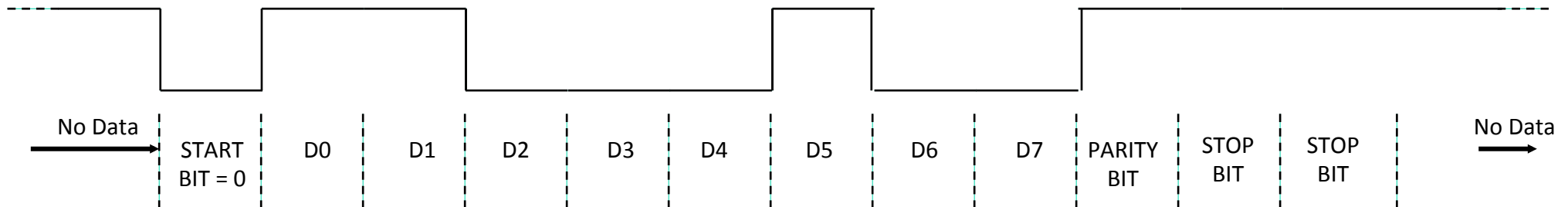
$$V = A e^{-t/\tau} \quad \text{for falling exponential}$$

τ is often called time constant, and it is the time for the signal to reach 63% of the final value for a rising exponential and 37% for a falling exponential.



Complex digital signal - UART

- ◆ Finally, in digital electronics, we often use digital signals to convey information by sending '1's and '0's at different times.
- ◆ One common example is a serial data standard known as Universal Asynchronous Receiver/Transmitter (UART) signal.



- ◆ Normally, the signal is a logic '1' (or high voltage).
- ◆ It goes low for one clock period – this is known as the **START bit**.
- ◆ The signal then goes high or low depending on the value of **DATA bits**, least significant bit first. Therefore the 8-bit data represented by this signal is 00100011 (35 decimal or 23 hex).
- ◆ There follows another bit known as **PARITY bit**. This is optional and may be absent (i.e. no parity). It may be **ODD** parity, which means that this bit is 1 or 0 such that the total number of '1's in the data stream + the parity bit is **ODD**. (Similarly for **EVEN** parity).
- ◆ Finally the data signal is high for either 1 or 2 bit periods – it is called the **STOP BIT(s)**.
- ◆ 1/bit period (or bit frequency) is called **baudrate** (or number of bit periods per second).

ASCII codes

- ◆ Computers often communicate with the keyboard using serial data format such as the UART signal.
- ◆ The information carried by the signal in its data bit is coded using an old standard known as **American Standard Code for Information Interchange (ASCII)**.
- ◆ Therefore the example waveform shown in the previous slide is a UART signal that represent the character “#”.