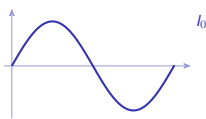


Alternating Currents

A2 Physics ■ Topic 21

A-Level Physics



Alternating Currents

What we will cover

- 1 Alternating current basics
- 2 Power in a resistor
- 3 Root-mean-square values
- 4 Rectification and smoothing
- 5 Recap

1 AC basics



Alternating Currents

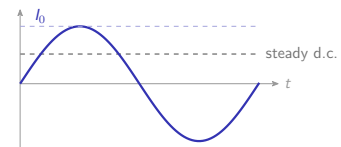
└ AC basics

Current that keeps reversing

An **alternating current** 交流电 keeps reversing direction. Mains is sinusoidal:

$$I = I_0 \sin(\omega t), \quad V = V_0 \sin(\omega t)$$

For a purely resistive load, V and I are in phase.



Alternating Currents

└ AC basics

The words on a CRO trace

period T

time for one full cycle. $f = 1/T$. Mains is 50 or 60 Hz.

angular frequency

$$\omega = 2\pi f = 2\pi/T$$

peak I_0 or V_0

the largest value in a cycle (amplitude)

peak-to-peak

$2I_0$ – from $+I_0$ to $-I_0$; useful on a CRO

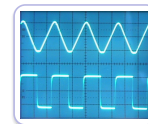
Alternating Currents

└ AC basics

Reading a CRO

Same as any wave (Topic 7), using a **cathode-ray oscilloscope** 示波器:

- horizontal divisions $\times$ **time-base** 时基 $\rightarrow$ period T , so $f = 1/T$
- vertical divisions $\times$ y -gain $\rightarrow$ peak voltage V_0 (centre to peak, or peak-to-peak then halve)



2 Power

Alternating Currents
└ Power

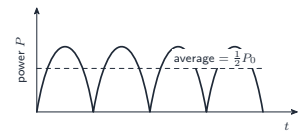
Power in a resistor pulses at $2f$

Instant power $P(t) = I(t)^2 R$. With
 $I = I_0 \sin(\omega t)$:

$$P(t) = I_0^2 R \sin^2(\omega t)$$

Always positive; peak $I_0^2 R$; minimum zero;
oscillates at **twice** the frequency of I . The
mean of $\sin^2$ over a cycle is $\frac{1}{2}$, so

$$\langle P \rangle = \frac{1}{2} I_0^2 R = \frac{1}{2} P_{\text{peak}}$$



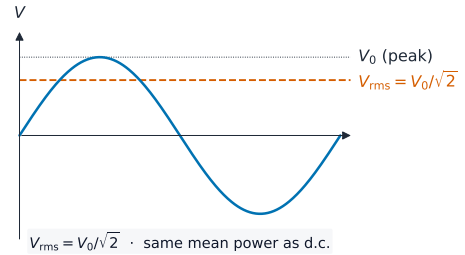
Average a.c. power in a resistor is **half the peak power**.

3 Root-mean-square

Alternating Currents
└ Root-mean-square

r.m.s. is the equivalent steady d.c.

$I_{\text{r.m.s.}}$ is the **steady direct current** giving the same average power in the same R .
 $I_{\text{r.m.s.}} = I_0 / \sqrt{2}$, $V_{\text{r.m.s.}} = V_0 / \sqrt{2}$.



Alternating Currents
└ Root-mean-square

Quoted a.c. values are r.m.s.

"230 V mains" means $V_{\text{r.m.s.}} = 230 \text{ V}$, so the peak is $230\sqrt{2} \approx 325 \text{ V}$. Components must be rated for the **peak**, not the r.m.s.

$$\langle P \rangle = I_{\text{r.m.s.}}^2 R = V_{\text{r.m.s.}}^2 / R = V_{\text{r.m.s.}} I_{\text{r.m.s.}}$$

Heater $R = 50 \Omega$ on 230 V r.m.s. mains

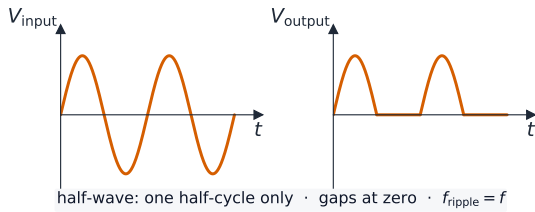
$$I_{\text{r.m.s.}} = 230 / 50 = 4.6 \text{ A}$$

$$\langle P \rangle = 230 \times 4.6 \approx 1.1 \times 10^3 \text{ W}$$

4 Rectification

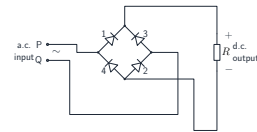
Half-wave – one diode, half the cycle

Rectification 整流 turns a.c. into one-direction voltage using **diodes** 二极管. A **single diode** passes only the positive half; the negative half is **reverse-biased** 反向偏置. Mean output $V_0/\pi \approx 0.32V_0$.



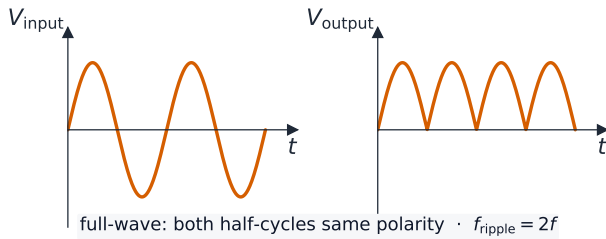
Full-wave – a four-diode bridge

A **bridge rectifier** 桥式整流器 uses **four diodes** so the load current always flows the same way. Output: a continuous run of positive half-waves at **twice** the input frequency. Mean $2V_0/\pi \approx 0.64V_0$ — double the half-wave value.



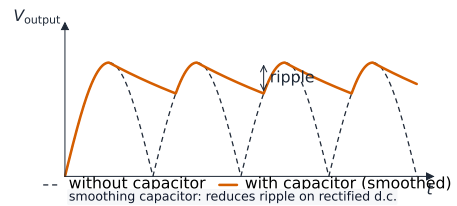
The rectified output

Full-wave flips the negative half rather than discarding it, so the output never rests at zero and its mean is **twice** the half-wave value.



Smoothing – a capacitor across the load

The capacitor charges to near the peak, then **discharges through the load** (time constant RC) while the diodes are cut off. The dips left are the **ripple** 纹波: smaller for larger C , larger R , or full-wave rectification.



5

Recap

Topic 21 – key takeaways

1 a.c.

$$I = I_0 \sin(\omega t); f = 1/T; \omega = 2\pi f$$

2 r.m.s.

$$I_{\text{rms}} = I_0/\sqrt{2}; \text{ power uses r.m.s.}$$

3 Rectify

one diode (half) or four-diode bridge (full)

4 Smooth

C in parallel with R ; large $RC \Rightarrow$ small ripple

Check yourself

- 1 Peak of 230 V r.m.s. mains?
- 2 Average power in a resistor, as a fraction of peak power?
- 3 How many diodes in a bridge rectifier?
- 4 Two ways to reduce ripple?

Answers 1. ≈ 325 V 2. half 3. four 4. larger C or R , or full-wave (higher frequency)