

ECE 215/S – Principles of Electronic Cyber Warfare

Block 1: Resistive Circuits and Power Distribution

Lesson 10: Power Converters

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Objective 1.7

I can calculate the efficiency, source voltage, and current of a power transmission system with one or more power converters.

- Same analysis skeleton as Lesson 9 — only the box in the middle changes
- Assessed on **Quiz 3** along with Objective 1.6

Where We Are Going

By the end of this lesson, you will be able to:

- Name the **four types** of power conversion and what each is for
- Explain what a **rectifier** and an **inverter** do
- Apply converter **efficiency** in a multi-stage power chain
- Find the **source voltage and current** required to feed a specified load

Why Convert at All?

Modern platforms run **both** kinds of power at once:

- Most electronic and **avionics** loads are **DC**
- **Actuation** systems are frequently **AC**
- High-power motors are usually **AC**
- Generation and distribution are **AC**; batteries are **DC**

So every real system needs devices that **convert** between them — and each one costs you efficiency.



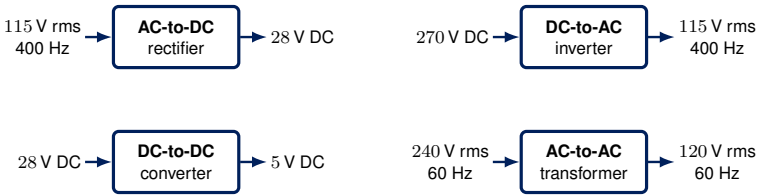
The **nameplate** says the same thing in text:

INPUT 100–240 V ∼, 50/60 Hz
OUTPUT 5.0 V ⎓, 1.0 A

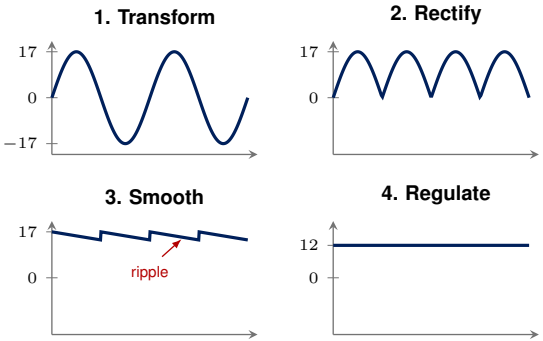
A phone charger is an AC-DC converter. So is every power supply in the aircraft.

The Four Conversions

- **AC→DC — rectifier.** Bus or wall power to device power. The most common conversion in existence
- **DC→DC — converter.** Change a DC level: a 28 V battery bus down to a 5 V logic bus
- **DC→AC — inverter.** Battery or solar DC into AC for motors or an AC bus
- **AC→AC.** Change AC voltage (a transformer, Lesson 9) or AC *frequency* (a cycloconverter)



AC to DC: Four Stages



Volts on each vertical axis; time runs left to right.

- **Transform.** A transformer (Lesson 9) steps the line down to 17 V peak
- **Rectify. Diodes** pass current one way only, folding the negative half up
- **Smooth.** A **filter capacitor** fills the gaps; what is left of the wiggle is **ripple** — *Lesson 15 covers filters properly*
- **Regulate.** A **regulator** holds the output flat at 12 V as load and line move

Every wall wart and aircraft power supply does all four.

DC to DC and DC to AC

DC-DC conversion

- Switches the input on and off very fast, then filters the result
- **Buck** converter steps voltage down; **boost** steps it up
- Typically 85–95% efficient

DC-AC inversion

- Switches DC back and forth to synthesize an AC waveform
- Output quality ranges from a crude square wave to a clean sinusoid
- Solar arrays, UPS units, and aircraft emergency AC buses

Every conversion is a switching operation, and every switch costs you power.

Converters Have Efficiency Too

A converter is just another stage in the chain from Lesson 8:

$$\eta_{\text{conv}} = \frac{P_{\text{out}}}{P_{\text{in}}} \qquad \Longrightarrow \qquad P_{\text{in}} = \frac{P_{\text{out}}}{\eta_{\text{conv}}}$$

- Cascade a transformer, a rectifier, and a DC-DC converter and the efficiencies **multiply**
- $0.97 \times 0.90 \times 0.92 = 0.803$ — roughly a fifth of the input is gone as heat before the load sees anything
- That heat has to go somewhere, which is why power electronics have heat sinks and fans

Method: Analyzing a Converter Chain

1. Find the **real power at the output** of the converter (that is the load's demand)
2. Use efficiency to find the **real power at the input**: $P_{\text{in}} = P_{\text{out}}/\eta$
3. Turn that real power into a **current** at the same point. On an **AC** segment take the Lesson 7 route — apparent power first, then current:

$$S = \frac{P}{\text{pf}} \quad \Longrightarrow \quad I_{\text{rms}} = \frac{S}{V_{\text{rms}}} \quad \text{with} \quad \text{pf} = \cos\phi, \;\; \phi = \phi_V - \phi_I$$

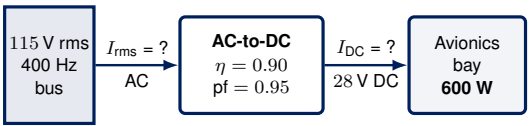
4. Repeat for each upstream stage until you reach the source
5. **Check:** $\eta_{\text{total}} = P_{\text{load}}/P_{\text{source}}$, and the stage efficiencies multiply to the same number

Step 3 only when I, a breaker, or S is asked — efficiency stops at step 2, pf or not.

Power factor only enters on AC segments.
On DC, pf $= 1$, so $S = P$ and $I = P/V$.

Worked Example

An avionics bay draws **600 W** of DC power at 28 V. It is fed by an AC-DC converter that is **90%** efficient, running off a 115 V RMS, 400 Hz aircraft bus at a power factor of **0.95**.



Careful on step 3: the bus is AC, so power factor is in play. *Work it before the next slide.*

Find:

1. The DC current into the avionics bay
2. The real power drawn from the AC bus
3. The RMS current drawn from the AC bus
4. The power dissipated in the converter

Worked Example — Solution

DC side (output)

$$I_{\text{DC}} = \frac{600}{28} = 21.4\,\text{A}$$

Real power at the input

$$P_{\text{in}} = \frac{600}{0.90} = 666.7\ \text{W}$$

Converter losses

$$P_{\text{loss}} = 666.7 - 600 = 66.7\ \text{W}$$

AC bus — apparent power first, then current:

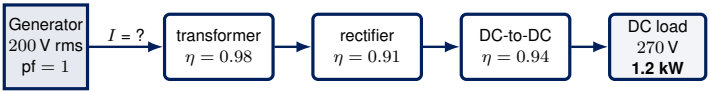
$$S = \frac{P_{\text{in}}}{\text{pf}} = \frac{666.7}{0.95} = 701.8\ \text{VA}$$

$$I_{\text{rms}} = \frac{S}{V_{\text{rms}}} = \frac{701.8}{115} = 6.10\,\text{A}$$

The bus carries **701.8 VA** to deliver 666.7 W, and 66.7 W of that never leaves the converter — it needs a heat sink, and the bay needs cooling.

Your Turn

A DC load requires **1.2 kW** at $270\,\text{V}$. The chain from the generator is:



1. What is the overall efficiency of the chain?
2. How much power must the generator supply?
3. What RMS current does the generator bus supply?
4. How much total power is lost as heat across the three stages?

Wrap-Up

Key ideas:

- Real systems carry both AC and DC, so converters are unavoidable
- **Rectifier** AC→DC, **inverter** DC→AC, DC-DC changes level, AC-AC level or frequency
- Four AC-DC stages: **transform, rectify, smooth, regulate**; what is left is **ripple**
- A converter is just another efficiency stage: $P_{\text{in}} = P_{\text{out}}/\eta$, and stages **multiply**
- Power factor applies only on **AC** segments: there, $S = P/\text{pf}$ and $I_{\text{rms}} = S/V_{\text{rms}}$

Next lesson:

- **Lesson 11 — Objective 1.8: Decision Matrices.** How to choose between designs when no option wins on every measure
- **Quiz 2** (Objectives 1.3–1.5) is due tonight