

ECE 215/S – Principles of Electronic Cyber Warfare

Block 2: Signal Processing

Lesson 18: Midterm Review

Department of Electrical and Computer Engineering
United States Air Force Academy

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Midterm Logistics

Lesson 17's analog filters (Objective **2.4**) are *not* on the midterm — the exam stops at Objective 2.3, and 2.4 is assessed on Quiz 5.

- **Take-home** examination, assigned, graded, and returned via **Gradescope**
- Due at **Lesson 19**. Covers **Objectives 1.1–1.7 and 2.1–2.3**; Objective 1.8 is assessed through Project 1, not here
- You have **125 minutes** once you start — take-home does not mean untimed
- **Individual effort.** Authorized: a calculator, the equation sheet, and **your own notes and slides on paper**. **No computer, no website** (course site included), **no GenAI** once you start
- The exam stays under **permanent academic security**: do not discuss its contents with anyone but your instructor until it is released
- Worth **15%** of your final grade — and **30%** of your Prog grade

One-time examination. There are no retakes, and no regrades.

How It Is Graded

Each problem earns one of three scores:

- **1** — correct framework, given data used correctly, neat and organized. Trivial math errors only
- **0.5** — correct framework, but given data used *incorrectly*. Still neat and organized
- **0** — wrong framework, or work that is not neat and organized, or nothing attempted

Three mechanics are scored on every problem, not assumed:

- **Engineering notation and units** — a decimal with a prefix (12.43 μV), never a fraction or a square root
- **Completely label every diagram**: each axis with its variable *and* its unit; every circuit with its polarities and current directions
- **Assign each page to its problem** in Gradescope, right side up and in order

Naming the right framework earns half the credit. Make that choice visible on the page.

Equation Sheet Tour

- You get **the ECE 215 equation sheet** — the same single sheet you use on every quiz and on the final. **Read it before you start**
- It gives equations, **not methods**. It will not tell you which current belongs in I^2R, or whether power factor applies on a given segment
- It also uses its own names: the sheet writes V_m where we wrote A, R_{eq} where we wrote R_{EQ}, and I_{nom} where we wrote I_s. Same quantities
- For Objective 2.3, look in **Complex Math** for the sinusoid $\leftrightarrow$ phasor row, and in **R-C and R-L Circuits** for the line that the series, parallel, and divider rules apply to Z — and the **Ideal Filters** table just below it covers Objectives 2.1–2.2
- Practice problems **PP01–PP09, PP12, and PP13** cover exactly the midterm's objectives — work them **before** exam day, with the sheet in front of you
- **Before** the exam, use everything you have — print or write out what you want beside you. **Once you start**: paper only — your notes, slides, the sheet, and a calculator. No computer, website, or AI

Refresher: Circuit Analysis and Protection (1.1–1.2)

- $V = IR, \quad P = IV = I^2R = V^2/R$
- Series: $R_{\text{EQ}} = \sum R$, same current, voltage divides. Parallel: same voltage, current divides
- **Voltage divider** uses the element's *own* R on top: $V_x = (R_x/R_{\text{EQ}})\, V_{\text{series}}$
- **Current divider** puts the element's *own* R on the bottom: $I_x = (R_{\text{EQ}}/R_x)\, I_{\text{parallel}}$, with R_{EQ} the *parallel* equivalent. With exactly **two** branches that collapses to $R_y/(R_x + R_y)$ — the shortcut is useless on three
- KVL around any loop $= 0$; KCL at a node: $\sum I_{\text{in}} = \sum I_{\text{out}}$
- Protection rating window: $1.1\, I_{\text{nom}} < CB_{\text{value}} < 1.5\, I_{\text{nom}}$, where I_{nom} is the current **through the protected element** — not always the source current. Then choose from the given table
- **Check every answer with conservation of power**

Refresher: AC and Power (1.3–1.5)

- $v(t) = V_{\text{bias}} + A\cos(2\pi f t + \phi)$; $T = 1/f$; $\phi = \omega\,\Delta t = (360^\circ/T)\,\Delta t$, with Δt measured **left** of the origin giving $\phi > 0$, which **leads**
- $V_{\text{rms}} = \sqrt{V_{\text{bias}}^2 + V_{pk}^2/2}$, which reduces to $V_{pk}/\sqrt{2}$ **only when** $V_{\textbf{bias}} = 0$. Convert *before* using any power equation
- With $\phi = \phi_V - \phi_I$: $P = V_{\text{rms}} I_{\text{rms}} \cos\phi$ (W), $Q = V_{\text{rms}} I_{\text{rms}} \sin\phi$ (VAR), $S = V_{\text{rms}} I_{\text{rms}}$ (VA)
- $S^2 = P^2 + Q^2$, pf $= \cos\phi = P/S$. $Q > 0$ is **lagging**, $Q < 0$ is **leading** — so lagging fixes the sign of $Q = \pm\sqrt{S^2 - P^2}$
- On a bus, P and *signed* Q add separately: $P_{\text{bus}} = \sum P$, $Q_{\text{bus}} = \sum Q$, then $S_{\text{bus}} = \sqrt{P_{\text{bus}}^2 + Q_{\text{bus}}^2}$. S does **not** add
- $\eta = P_{\text{out}}/P_{\text{in}} = P_{\text{useful}}/(P_{\text{useful}} + P_{\text{loss}})$; cascaded stages **multiply**; $P_{\text{in}} = P_{\text{out}}/\eta$
- 1 hp $= 745.7$ W

Refresher: Transmission and Conversion (1.6–1.7)

- $a = \dfrac{N_1}{N_2} = \dfrac{V_1}{V_2} = \dfrac{I_2}{I_1}$; $a < 1$ steps **up**, $a > 1$ steps **down**
- $R_{\text{line}} = r\,d$, with r in Ω/km
- Line **loss** $= I^2 R_{\text{line}}$, computed with the current **in that segment** — not the load current
- Line **drop** $= IR_{\text{line}}$. The drop and the loss are different questions: the transformer sees $V_{\text{source}} - V_{\text{line}}$, so a KVL step comes first
- Converters are efficiency stages: $P_{\text{in}} = P_{\text{out}}/\eta$
- Power factor applies on **AC segments only**. On DC, pf $= \cos\phi = 1$
- **Work from the end you are given** — backward from the load when the load is specified, forward from the source when the source voltage, current, or pf is

Refresher: Frequency Domain and Filters (2.1–2.2)

- One sinusoid in time is **one spike** in frequency; DC sits at $f = 0$
- $BW = f_{\text{high}} - f_{\text{low}}$ — and $f_{\text{low}} = 0$ when DC is present
- Four ideal types: LPF, HPF, BPF, and **BSF**, also written **BRF** (band-reject). Each input spike **survives untouched or vanishes**
- Capacitors **block DC, pass highs**; inductors do the reverse
- Asked to *draw* a spectrum? Label both axes with a variable **and** a unit — f in Hz across, $|V(f)|$ in V up — and print the height of every spike

Refresher: Impedance (2.3)

- $Z_R = R, \quad Z_C = \dfrac{1}{j\omega C}, \quad Z_L = j\omega L$, with $\omega = 2\pi f$
- $1/j = -j$, so $Z_C = -\dfrac{j}{\omega C}$ — that is how $1/j\omega C$ turns into a number like $-j25\,\Omega$
- Ohm's Law is still $V = IZ$, and the **voltage divider is unchanged**: $V_x = V_s\, Z_x / Z_{\text{EQ}}$. Only the numbers are complex
- **Add** in rectangular; **multiply and divide** in polar — multiply magnitudes and add angles, divide magnitudes and subtract angles
- $A = \sqrt{Re^2 + Im^2}, \quad \phi = \tan^{-1}(Im/Re)$. Check the quadrant, and check that your calculator is in **degrees**

Objective 2.3 is the one midterm objective with no quiz behind it — Quiz 4 stops at 2.2 and Quiz 5 is not due until Lesson 21. Give this frame the most rehearsal.

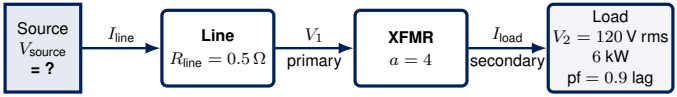
Common Errors — Quizzes 1–3 and the Practice Problems

- **Two-resistor current-divider shortcut used on three branches** — the general rule is $I_x = (R_{\text{EQ}}/R_x)I_{\text{parallel}}$
- **Breaker sized off the wrong current** — use the current in the branch the breaker protects
- P **and** Q **added arithmetically** rather than as a right triangle
- **Peak used where RMS was required**, or the reverse
- **Turns ratio inverted for current** — $a = I_2/I_1$
- **Load current used for line loss** instead of the line current
- **DC forgotten when deciding what survives a filter** — and when a DC term is present, $f_{\text{low}} = 0$

Most lost points are method errors, not arithmetic.

Worked Review Problem

A transmission line ($R_{\text{line}} = 0.5\,\Omega$) feeds a transformer with $a = 4$, which supplies a 120 V RMS load drawing 6 kW at pf $= 0.9$ lagging. **Find the source voltage and the efficiency of the transmission.**



1. Load side (1.4). $S = P/\text{pf} = 6000/0.9 = 6.67$ kVA, so $I_{\text{load}} = S/V_2 = 55.56$ A

2. Through the transformer (1.6). $I_{\text{line}} = I_{\text{load}}/a = 13.89$ A and $V_1 = aV_2 = 480$ V

3. Up the line (1.6). $V_{\text{line}} = I_{\text{line}} R_{\text{line}} = 6.94$ V, so $V_{\text{source}} = 480 + 6.94 = \mathbf{486.9}$ V

4. Line loss (1.3, 1.6), then efficiency (1.5). $P_{\text{line}} = I_{\text{line}}^2 R_{\text{line}} = 96.5$ W, so

$$\eta = \frac{6000}{6000 + 96.5} = \mathbf{98.4}\%$$

Carry full precision to the last step; round only the answer. **Ten problems, one point each, one objective apiece** — work them in whatever order suits you, and name your framework on every page.

Wrap-Up

- The midterm covers **Objectives 1.1–1.7 and 2.1–2.3** — not 1.8, and not Lesson 17's 2.4
- Scored **1** / **0.5** / **0** — the right framework, shown clearly, is worth at least half
- Work practice problems **with the equation sheet in front of you**, before exam day
- EI is available. Use it before the deadline, not after

Due tonight:

- **Quiz 4** (Objectives 2.1–2.2)

Next lesson:

- **Lesson 19 — Analog Filter Lab. Midterm is due** at the start of class. Bring your laptop and turn it in before you pick up a probe — then you build and measure the Lesson 17 filters with a partner