Block 24 — Wrap-up and Applications

Student Group

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24.0 Intro

24.0.1 Learning objectives

After this 90-minute block, you can

- connect the different negative-feedback op-amp circuits (Blocks 21–23) into a coherent system view.
- explain how negative feedback determines gain, impedance, and linearity in practical op-amp circuits.
- select an appropriate op-amp circuit (buffer, amplifier, summing, differential, transimpedance, transconductance) for a given application.
- analyze complete signal chains consisting of several op-amp stages.
- recognize practical limitations of real op-amp circuits (supply rails, saturation, loading, offsets).
- interpret op-amp circuits as signal converters (voltage–voltage, current–voltage, voltage–current).

24.0.2 Conceptual overview

- All op-amp circuits in Blocks 21–23 are variations of one single idea:

a high-gain amplifier whose output is fed back in a controlled way.

- Negative feedback forces the differential input voltage $U_{\rm D}$ to become very small, which makes the circuit behavior depend almost entirely on external components, not on the op-amp itself.
- Resistors do not merely "limit current" here — they define signal relationships (ratios, sums, differences).
- Many circuits that look different (buffer, amplifier, converter) are mathematically and conceptually closely related.
- Thinking in terms of signal flow and conversion is the key step from circuit theory to real engineering applications.

24.1 Core content

24.1.1 From individual circuits to a system

In Block21, Block22 and Block23, several op-amp circuits were introduced one by one. At first glance, these circuits may appear unrelated.
However, they can all be understood as special cases of the same feedback principle.

A practical electronic system rarely uses just one op-amp stage. Instead, several stages are cascaded, each fulfilling a specific role:

- Input stage: impedance matching (voltage follower).
- Scaling stage: amplification or attenuation (inverting / non-inverting).
- Combination stage: summing or subtraction (summing / differential amplifier).
- Interface stage: signal conversion (current–voltage or voltage–current).

Understanding why each stage is used is more important than memorizing formulas.

24.1.2 Negative feedback as an engineering tool

Negative feedback provides three essential properties simultaneously:

- **Defined gain**
  The closed-loop gain depends on resistor ratios, not on $A_{\rm D}$.

- **Stability and linearity**
  Small nonlinearities inside the op-amp are strongly suppressed.

- **Impedance shaping**
  High input resistance and low output resistance can be achieved at the system level.

These properties explain why op-amps are ubiquitous in analog electronics.

24.2.3 Typical application patterns

Some recurring patterns appear across many applications:

- **Sensor readout**
  Sensors often deliver currents or small voltages → transimpedance amplifier → voltage amplifier.

- **Signal conditioning**
  Offset removal and scaling → differential amplifier + non-inverting amplifier.

- **Summation and mixing**
  Multiple signals combined with weighting → summing amplifier.

- **Actuator drive**
  Voltage command converted into controlled current → voltage-to-current converter.

Recognizing these patterns allows fast interpretation of unfamiliar circuits.