Block 24 — Wrap-up and Applications

Student Group

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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).

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.

Core content

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.

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.

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.