What Is a TEC Controller?

A Visual Engineering Guide to Thermoelectric Temperature Control

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Key Takeaway

> *A TEC controller is a closed-loop thermal servo that holds temperature to ±0.001 °C by continuously measuring, comparing, correcting, and driving a thermoelectric cooler. ATI's controllers add five user-tunable compensation components, full EMI shielding, and a patented topology — enabling engineers to achieve rock-solid stability matched to their specific thermal load.*

Executive Summary

A TEC controller is a closed-loop instrument that drives a thermoelectric cooler (TEC) to hold a thermal load at a programmable target temperature — with stability as fine as ±0.001 °C under specified test conditions (load-matched compensation, precision thermistor, stable ambient). This paper covers the physics from first principles, system architecture, PID compensation theory, ATI's seven engineering advantages, reliability considerations, applications, troubleshooting, and product selection — all illustrated with block diagrams and educational cartoons.

1. One-Sentence Definition

> *A **TEC controller** reads a temperature sensor, compares the measurement to a setpoint voltage, computes a PID correction signal, and delivers regulated bidirectional current to a thermoelectric cooler — continuously and automatically — forming a closed-loop thermal servo.*

2. Closed-Loop Controller vs. Driver vs. Discrete Op-Amp Loop

Engineers choosing a temperature-regulation approach face three options:

Criterion	TEC Controller Module (ATI)	TEC Driver (Open-Loop)	Discrete Op-Amp PID Loop
Feedback	Closed-loop (automatic)	None — host MCU must close the loop	Closed-loop (manual design)
Temperature stability	±0.001 °C (DAH grade)	Depends entirely on host firmware	Achievable, but requires extensive analog design
Time to working prototype	Minutes (eval board)	Days (write firmware, debug)	Weeks (select op-amps, passives, layout, iterate)
EMI performance	Full metal shielding (bidirectional)	Typically unshielded	Depends on layout — often poor
Board space	14×14 mm (Micro) to 36×36 mm	Varies — IC + passives + MOSFET + filter	Large — 20+ discrete components
Compensation tuning	5 socketed components (Rd, Cd, Ri, Ci, Rf) or Auto-PID	Software PID gains (requires thermal model)	Fixed passives — hard to change in production
Reliability	Proven module, 27+ years in production	Depends on firmware quality	Depends on component selection and aging
Cost at volume	Higher per-unit, but faster time-to-market	Lower BOM, higher NRE (firmware + debug)	Lowest BOM, highest NRE (analog design expertise)
Best for	Production systems needing guaranteed stability	Systems with existing MCU and loose temp specs	One-off lab instruments with analog design staff

Bottom line: If temperature stability matters and you want to ship product (not spend months debugging), a dedicated TEC controller module eliminates the riskiest variables. ATI's evaluation boards let you validate performance before committing.

→ See the full TEC Controller Selection Guide to find the right module for your application.

3. Thermal Physics — First Principles

3.1 The Peltier Effect

When DC current flows through a thermoelectric junction, heat is absorbed on one side and released on the other. The cooling power at the cold side is:

$$Q_c = \alpha \cdot I \cdot T_c - \frac{1}{2} \cdot I^2 \cdot R_{TEC} - K \cdot \Delta T$$

Where: - **α** = Seebeck coefficient (V/K) — determines how much heat the junction pumps per amp - **I** = TEC drive current (A) - **T_c** = cold-side absolute temperature (K) - **½ · I^2 · R_TEC** = Joule heating within the TEC pellets (always works against cooling) - **K · ΔT** = heat conduction back through the TEC from hot to cold side

The hot side must dissipate everything: **Q_h = Q_c + I^2 · R_TEC + P_controller_losses**. This is why heatsink sizing is critical — and why operating at low current fractions maximizes efficiency.

3.2 Thermal–Electrical Analogy

Temperature is voltage. Heat flow is current. Thermal resistance is electrical resistance. The same Ohm's law applies: **ΔT = Q × R_th**.

Electrical	Thermal	Unit	Analogy
Voltage (V)	Temperature (T)	°C	"Pressure" that drives heat flow
Current (I)	Heat flow (Q)	W	Rate of energy transfer
Resistance (R)	R_th	°C/W	Opposition to heat flow
Capacitance (C)	C_th (thermal mass)	J/°C	Energy storage — resists temperature change
τ = RC	τ_th = R_th × C_th	s	Time constant — how fast the system responds

Why this matters for control: A load with τ_th = 4 s (typical laser butterfly package) oscillates at approximately 16–24 s period when compensation is mismatched — invisible on an oscilloscope, devastating to a laser wavelength lock. A PCR thermal block with τ_th = 45 s oscillates at 3–5 minute periods. The compensation network must be tuned to the specific thermal load.

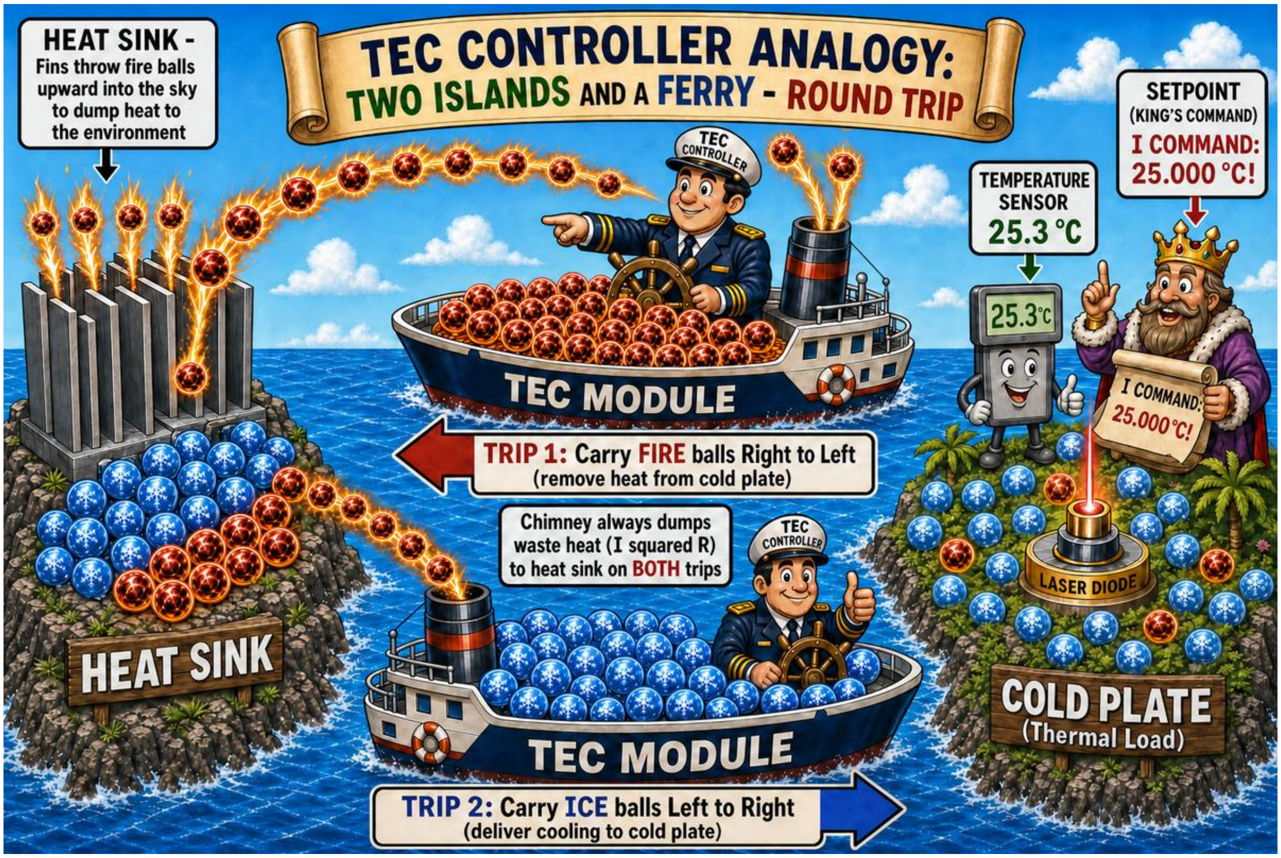


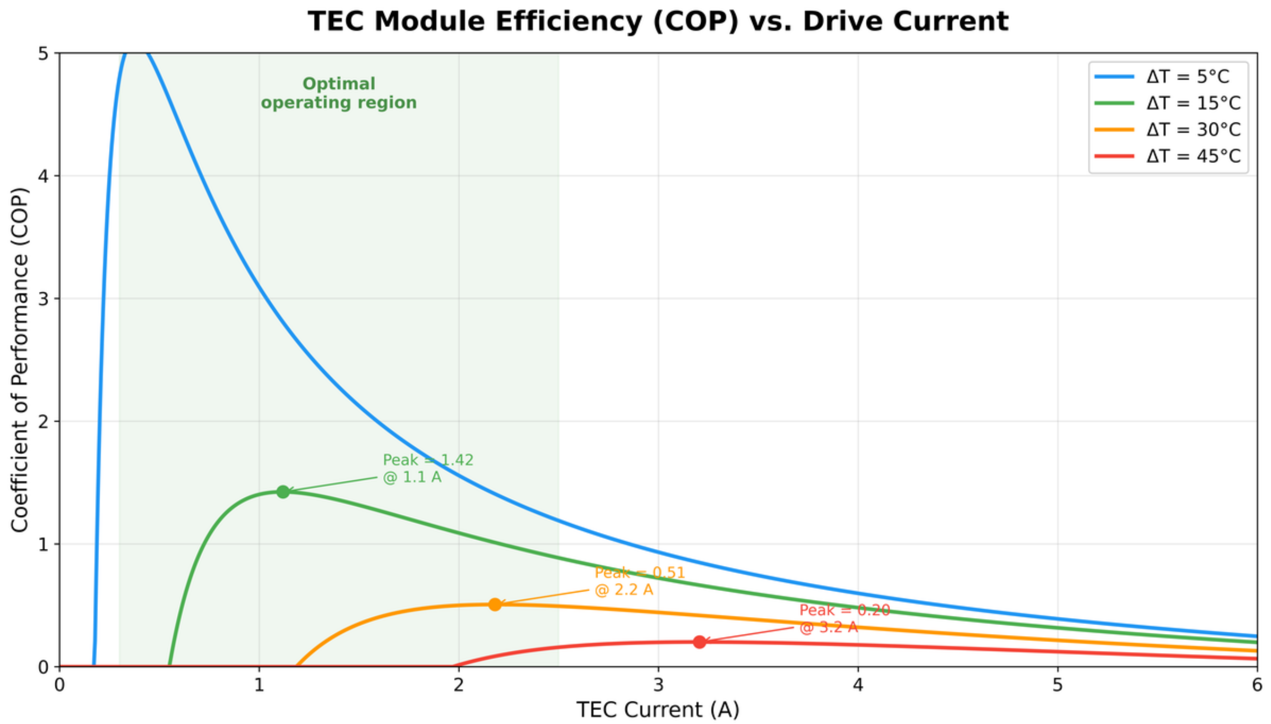
Figure 1 — Two Islands and a Ferry. The TEC module is a ferry that carries heat (fire balls) from the cold plate to the heat sink — and delivers cooling (ice balls) back. The TEC controller is the captain who reads the temperature sensor and adjusts how fast and which direction the ferry runs. Bidirectional: Trip 1 removes heat; Trip 2 delivers cooling. The chimney always dumps waste heat (I^2R) regardless of direction. *Design rule: The ferry (TEC) must be sized so it never runs at full speed — operate at 25–30% of capacity for best efficiency.*

3.3 Coefficient of Performance (COP)

COP = Q_c / P_electrical. For a TEC, COP peaks at low current fractions:

- At 25–30% of I_max: COP ≈ 2–4 at small ΔT (≤ 5–10 °C); typically < 1.5 at ΔT = 15–45 °C (most real applications)
- At 50% of I_max: COP drops by approximately half (illustrative; varies with ΔT and TEC model)
- At 100% of I_max: COP < 1 (more heat generated than pumped — emergency cooling only)

Design rule: Size the TEC so your operating point is 25–30% of I_max. This maximizes COP, minimizes hot-side dissipation, and extends TEC lifetime. Use ATI's TEC modules sized for your specific cooling load.



TEC Module Efficiency (COP) vs. Drive Current

All curves rise from zero, peak at optimal current, then fall — operating beyond the peak wastes power as Joule heating (I²R) dominates

Figure 2 — COP vs. Drive Current. All curves rise from zero, peak at the optimal current, then fall as Joule heating (I^2R) dominates. At ΔT = 5 °C (blue), COP exceeds 4 at low current. At ΔT = 45 °C (red), peak COP is only 0.2. The shaded region marks the optimal operating zone (25–30% of I_max). *Design rule: Size the TEC so your operating point falls in the green zone — maximum cooling per watt of input power.*

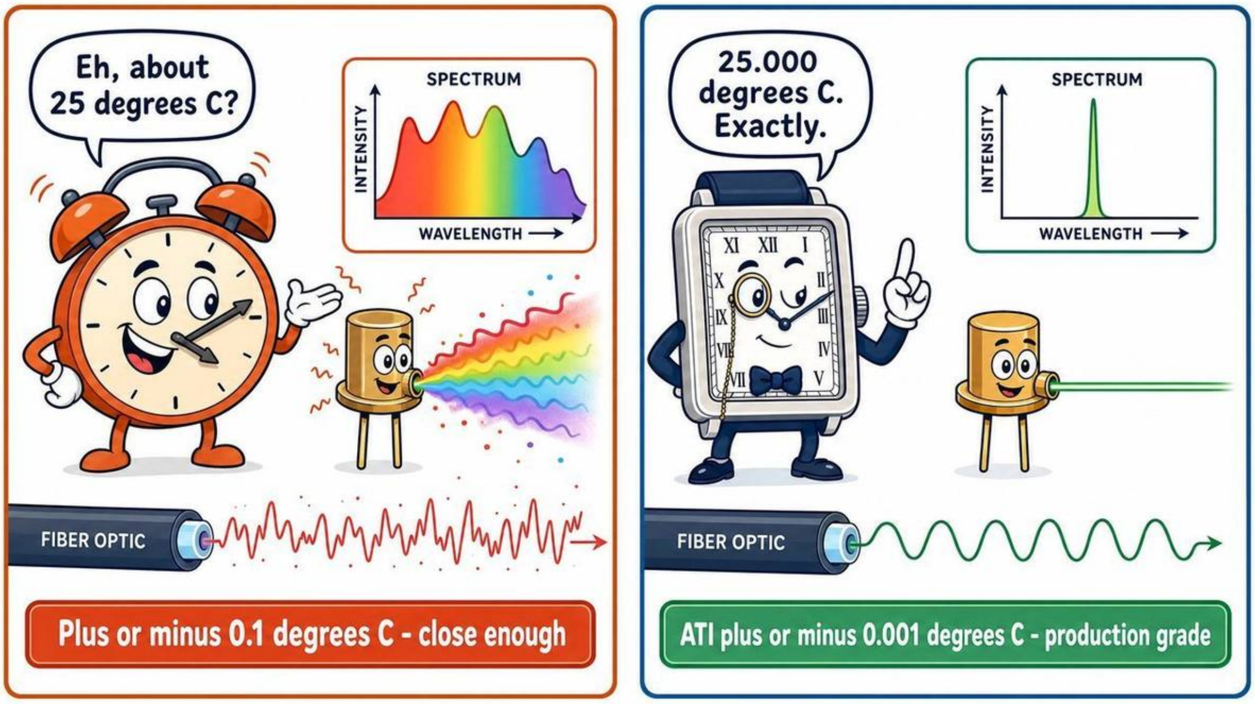


Figure 3 — Swiss Watch vs. Alarm Clock. ±0.1 °C is "close enough" for a kitchen timer. ±0.001 °C keeps a laser wavelength locked. *Design rule: Match compensation precision to the application requirement — don't over-specify (wastes money) or under-specify (system fails).*

4. System Architecture

4.1 Block Diagram

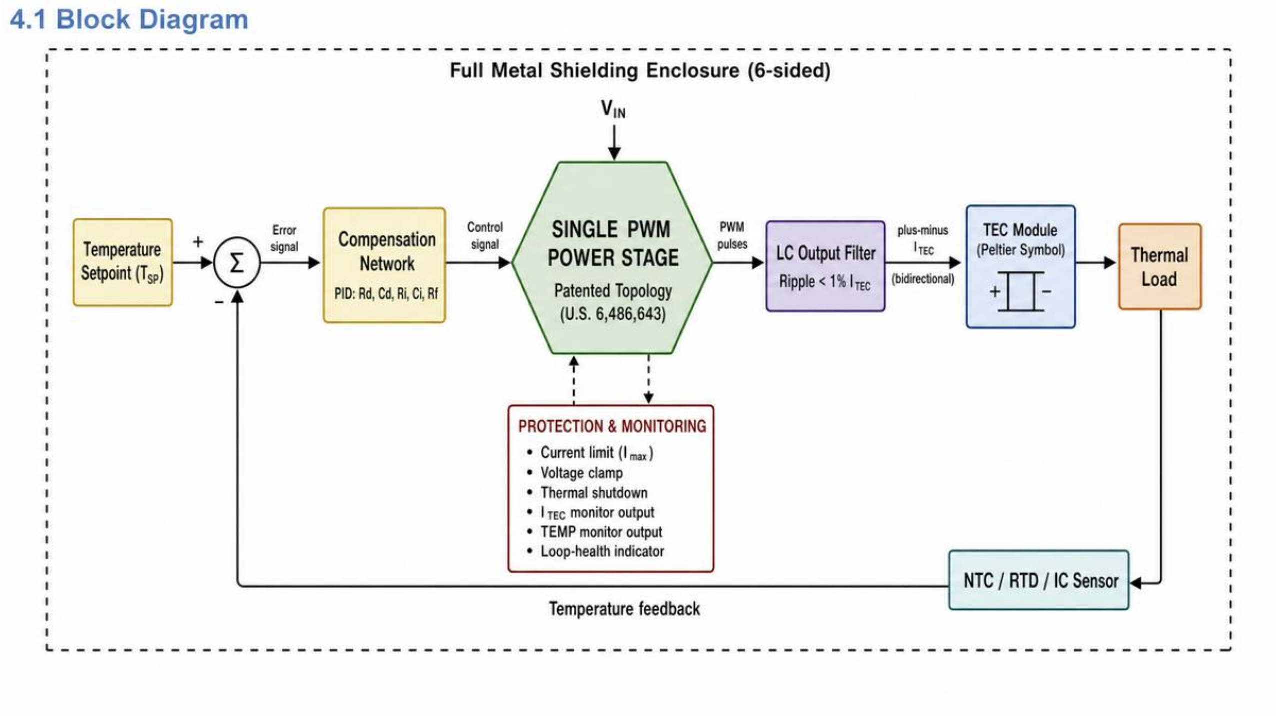


Figure 4 — TEC Controller Block Diagram. Complete signal flow from temperature setpoint through error amplifier, PID compensation network, patented single-PWM power stage (U.S. 6,486,643), LC output filter, to the TEC module and thermal load. Temperature feedback from NTC/RTD/IC sensor closes the loop. Protection and monitoring block provides current limit, voltage clamp, thermal shutdown, and diagnostic outputs. Full metal shielding enclosure (6-sided) surrounds the controller.

Signal flow in detail:

1. **Setpoint (TEMPSP pin):** A voltage representing the target temperature. Typically set by a DAC, potentiometer, or microcontroller. Range: 0–2.5 V (maps to the sensor's temperature range).
2. **Error Amplifier:** Subtracts the sensor feedback voltage from the setpoint. Output = (V_setpoint − V_sensor) × gain. When error is zero, the loop is in regulation.
3. **Compensation Network (PID):** Shapes the error signal's frequency response. Five external components (Rd, Cd, Ri, Ci, Rf) set the proportional gain, integral action, and derivative action. This is where the loop is tuned to match the thermal load's time constant.

4. **PWM Power Stage:** Converts the compensation output into a pulse-width-modulated drive signal. ATI's patented topology delivers bidirectional current efficiently — heating or cooling determined by duty cycle. No host software or external microcontroller required for the analog-compensation models.
5. **Output LC Filter:** Smooths the PWM pulses into clean DC current for the TEC. Reduces ripple current that would cause micro-oscillations in temperature. Typical ripple: <1% of I_TEC at switching frequency.
6. **TEC (Thermoelectric Cooler):** The Peltier module that does the actual heating/cooling. Current direction determines heat-flow direction.
7. **Temperature Sensor:** An NTC thermistor (default), platinum RTD, or semiconductor IC mounted on or near the thermal load. Converts temperature to a voltage that feeds back to the error amplifier.

4.2 Protection and Monitoring

Every ATI controller includes built-in protection and monitoring — no external components required:

Feature	Function	Why It Matters
Current limit	Caps I_TEC at a safe maximum	Prevents TEC damage from thermal shock
Voltage limit	Prevents over-voltage to TEC	Protects against open-sensor fault
Thermal shutdown	Disables output if controller overheats	Prevents cascade failure
TEMP output	Analog voltage proportional to measured temperature	Enables system-level monitoring
ITEC output	Analog voltage proportional to TEC current	Verifies operating point
Loop-health indicator	Flags when loop cannot reach setpoint	Detects heatsink failure or TEC degradation

5. PID Compensation — Theory and Practice

5.1 Why PID?

A thermal system is a low-pass plant with a dominant pole at $f = 1/(2\pi \cdot \tau_{th})$. To achieve zero steady-state error with adequate phase margin (>45°), the controller must provide:

- **Proportional (P):** Immediate correction proportional to error magnitude. Fast but leaves residual offset.

- **Integral (I):** Accumulates error over time, driving steady-state error to zero. Essential for precision. Too much causes slow oscillation.
- **Derivative (D):** Responds to rate of change — predictive damping. Reduces overshoot. Amplifies sensor noise if overdone.

5.2 The Five Compensation Components

ATI's analog PID implementation uses five passive components that engineers can select to match any thermal load:

Component	Controls	Effect of Increasing	Typical Range
Rd	Derivative gain	Faster high-frequency response, more noise	10 kΩ – 500 kΩ
Cd	Derivative time constant	Extends derivative action to lower frequencies	100 pF – 33 nF
Ri	Integral gain	Stronger low-frequency correction, risk of oscillation	22 kΩ – 500 kΩ
Ci	Integral time constant	Slower but more stable integral action	1 nF – 33 nF
Rf	Overall loop gain	Higher gain = tighter control but less stability margin	10 kΩ – 200 kΩ

Design rule for crossover frequency: Set f_c = 1/(5–10 × τ_th). For a laser butterfly with τ_th = 4 s, target f_c = 0.025–0.05 Hz. For a PCR block with τ_th = 45 s, target f_c = 0.002–0.004 Hz.

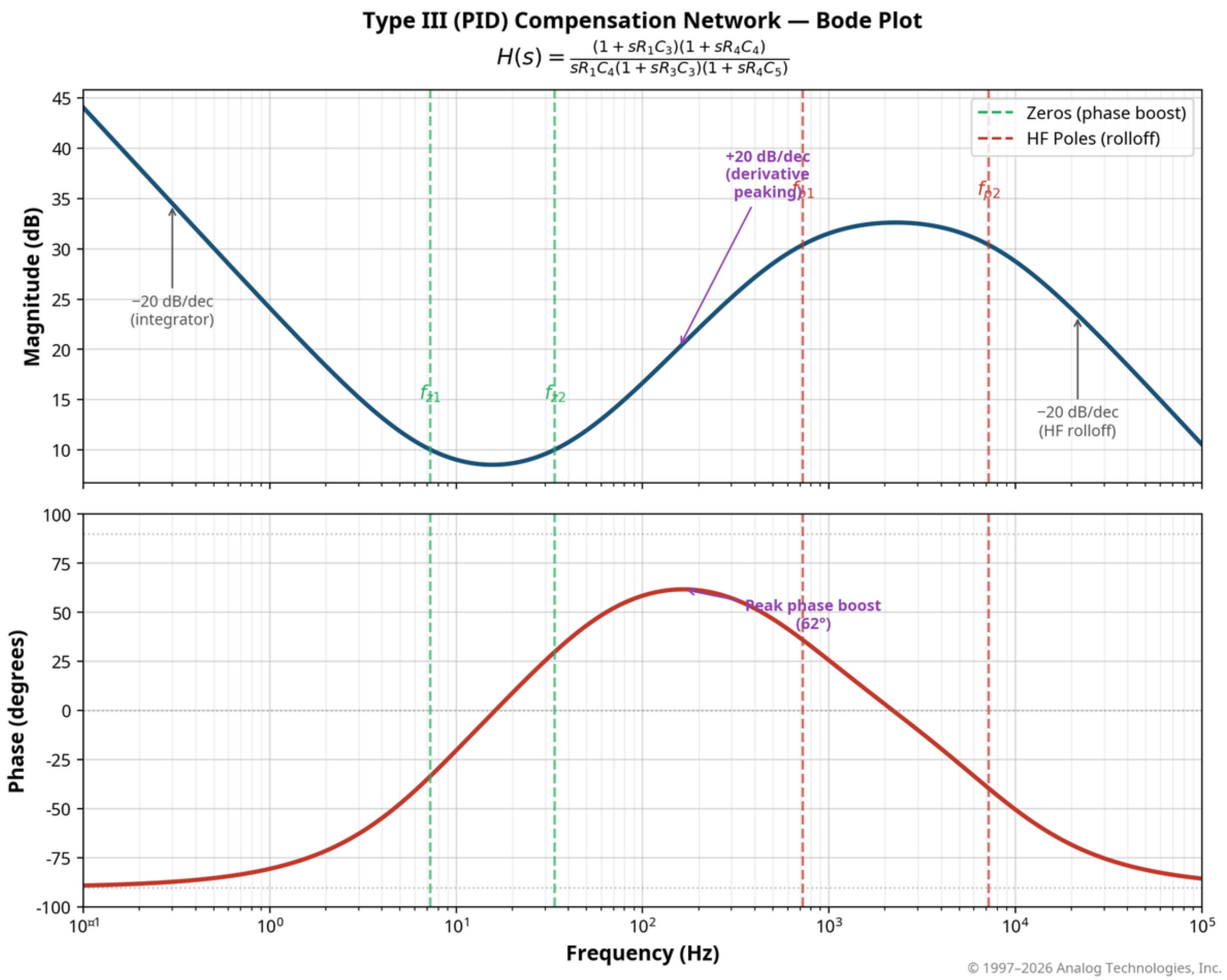


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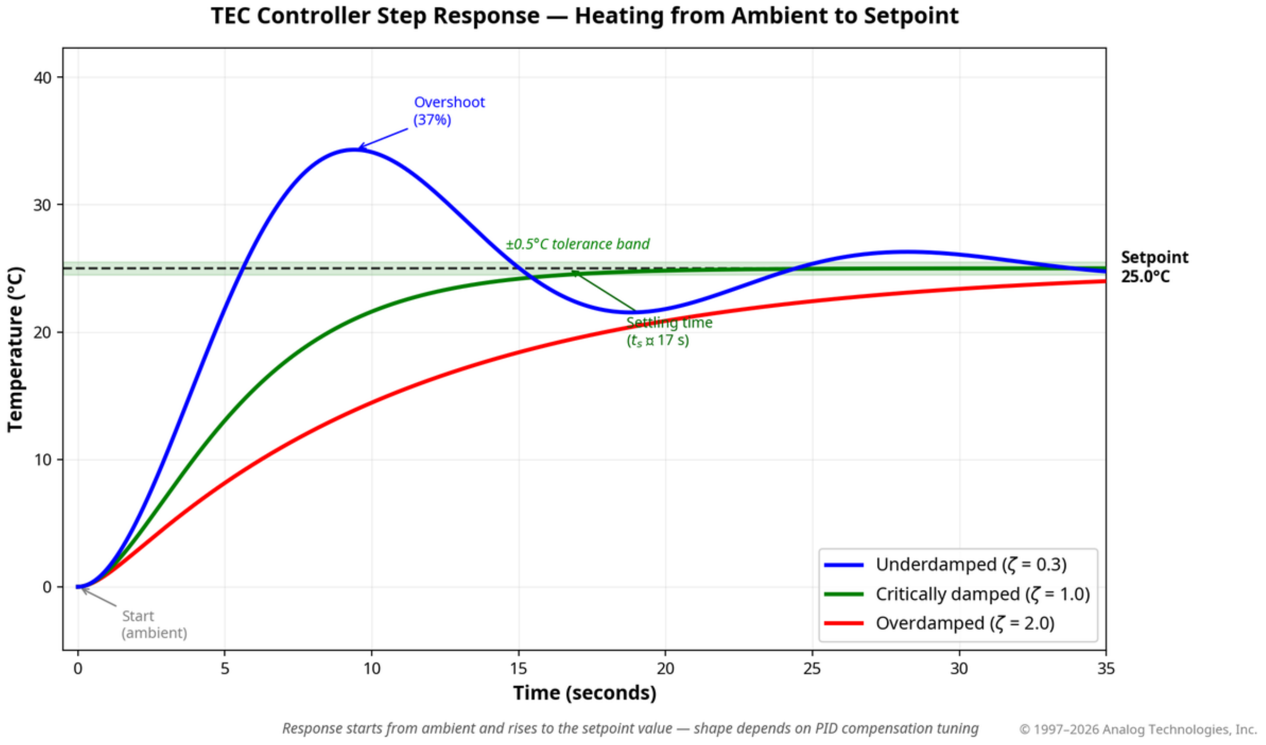
Figure 5 — Type III (PID) Compensation Bode Plot. Top: magnitude response showing integrator slope (−20 dB/dec), two zeros (f_z1, f_z2) that provide phase boost, derivative peaking (+20 dB/dec), and two high-frequency poles (f_p1, f_p2) for noise rolloff. Bottom: phase response showing peak phase boost of 62° at the geometric mean of the zeros — this is the phase margin the loop needs to remain stable. *Design rule: Place the crossover frequency f_c at the peak of the phase boost curve.*

5.3 Why Thermal PID Is Harder Than Electrical PID

Challenge	Electrical (MHz)	Thermal (mHz–Hz)
Time constant	µs – ms	seconds – minutes
Iteration time per tuning step	µs	5–15 minutes
Plant variation	±5% (components)	±50% (thermal interface, ambient)
Sensor delay	negligible	0.1–2 s (thermistor in epoxy)
Non-linearity	mild	severe (COP vs. ΔT, R_th vs. airflow)

This is why manual tuning is painful — and why ATI's evaluation boards and Auto-PID are so valuable.



Response starts from ambient and rises to the setpoint value — shape depends on PID compensation tuning

Figure 6 — TEC Controller Step Response. Three tuning scenarios for a setpoint change from ambient to 25.0 °C. Blue (underdamped, ζ = 0.3): fast rise but 37% overshoot — unacceptable for laser cooling. Green (critically damped, ζ = 1.0): settles in 17 s with no overshoot — the ideal target. Red (overdamped, ζ = 2.0): no overshoot but painfully slow. *Design rule: Tune for critical damping (ζ ≈ 0.7–1.0) using the evaluation board — fast settling with minimal overshoot.*

Figure 7 — The Tightrope of PID Tuning. Without Auto-PID, one wrong step and the system oscillates. Auto-PID is the safety net — perfect balance in 60 seconds. *Design rule: If your thermal load varies between production units, use Auto-PID to eliminate unit-to-unit tuning variation.*

6. Seven ATI Advantages

6.1 Patented Single-PWM Topology

ATI's patented topology (U.S. Patent 6,486,643 B2, inventor G. Liu, issued Nov 26, 2002; assigned to Analog Technologies, Inc. and licensed to Analog Devices, Inc. for TEC controller ICs) uses a single PWM switching element to deliver bidirectional TEC current — no shoot-through risk, no dead-time distortion, and inherently lower switching losses than multi-switch alternatives.

Metric	ATI Patented Topology	vs. Conventional Approaches
Switching losses	Lower (single element)	(baseline: multi-switch topologies, per ATI testing)
Component cost	~25% less	Fewer FETs, drivers, and passives
PCB area	~35% smaller	Single power path vs. multi-switch bridge
Efficiency	>92% typical	Measured on TEC18V15A

Note: The specific power-stage topology varies by product family to optimize performance at each power level. The patented single-PWM approach is the foundation of ATI's efficiency advantage across the line. Consult the product datasheet for topology details of each model.

Figure 8 — Efficiency Race. Single-PWM runs lean with one switching element — fewer components, no dead-time distortion. Multi-switch designs trade simplicity for higher current capacity. *Design rule: ATI's patented topology optimizes the power stage for each product family's target power level — consult the datasheet for your model.*

6.2 Auto-PID — Self-Tuning Compensation

Available across the TEC18V15A series (e.g., **TEC18V15ADAPID** in DIP) and the TEC28V15A series (e.g., **TEC28V15ASAPID** in SMT). Press one button → the controller injects a test signal, measures the plant response, identifies τ_th and gain, then configures optimal compensation automatically. Done in approximately 60 seconds.

The **TEC28V15A** is believed to be the world's first TEC controller module with a built-in Auto-PID compensation network.

When to use Auto-PID: - Load varies between production units (thermal interface variations) - Wide operating temperature range (τ_th changes with ambient) - Tuning time is critical (field deployment, production line) - Engineer lacks thermal control experience

When manual tuning is better: - Fixed, well-characterized load (laser module in production) - Ultra-low-noise requirement (Auto-PID's test signal briefly perturbs temperature) - Cost-sensitive high-volume (manual values burned into production)

6.3 Full Bidirectional EMI Shielding

Full metal enclosure blocks all coupling paths: capacitive, inductive, radiated, and conducted. Designed to meet CISPR 11 Class B emission limits at the module boundary (requires ATI confirmation of formal test report).

Why this matters: A TEC controller switching at 100–500 kHz sits millimeters from a laser diode, photodetector, or precision ADC. Without shielding, switching transients couple into sensitive analog circuits. ATI's shielded controllers eliminate this concern — zero measurable EMI at the module boundary under standard test conditions.

Critical for co-location with laser drivers, photodetectors, precision ADCs, and optical spectrum analyzers.

Figure 9 — The Noisy Neighbor. Unshielded controllers blast EMI through the walls into your sensitive circuits. ATI's shielded controller: zero noise in, zero noise out. *Design rule: If your TEC controller shares a PCB with analog signal paths, use a shielded module.*

6.4 User-Tunable Compensation Network

Every thermal load is different. A laser diode butterfly package (τ_th ≈ 4 s) needs completely different compensation than a PCR thermal block (τ_th ≈ 45 s). Generic "one-size-fits-all" compensation causes oscillation or sluggish response.

ATI's solution: All ATI TEC controllers expose **five tunable compensation components** — Rd, Cd, Ri, Ci, Rf — that you select to match your specific thermal load characteristics. Like a master tailor measuring each customer for a bespoke suit, you adjust these five values until the loop response perfectly fits your plant.

Result: Temperature stability optimized for YOUR load — not a generic average. Crossover frequency lands exactly where it should: f_c = 1/(5–10 × τ_th). Phase margin >45°. Zero steady-state error.

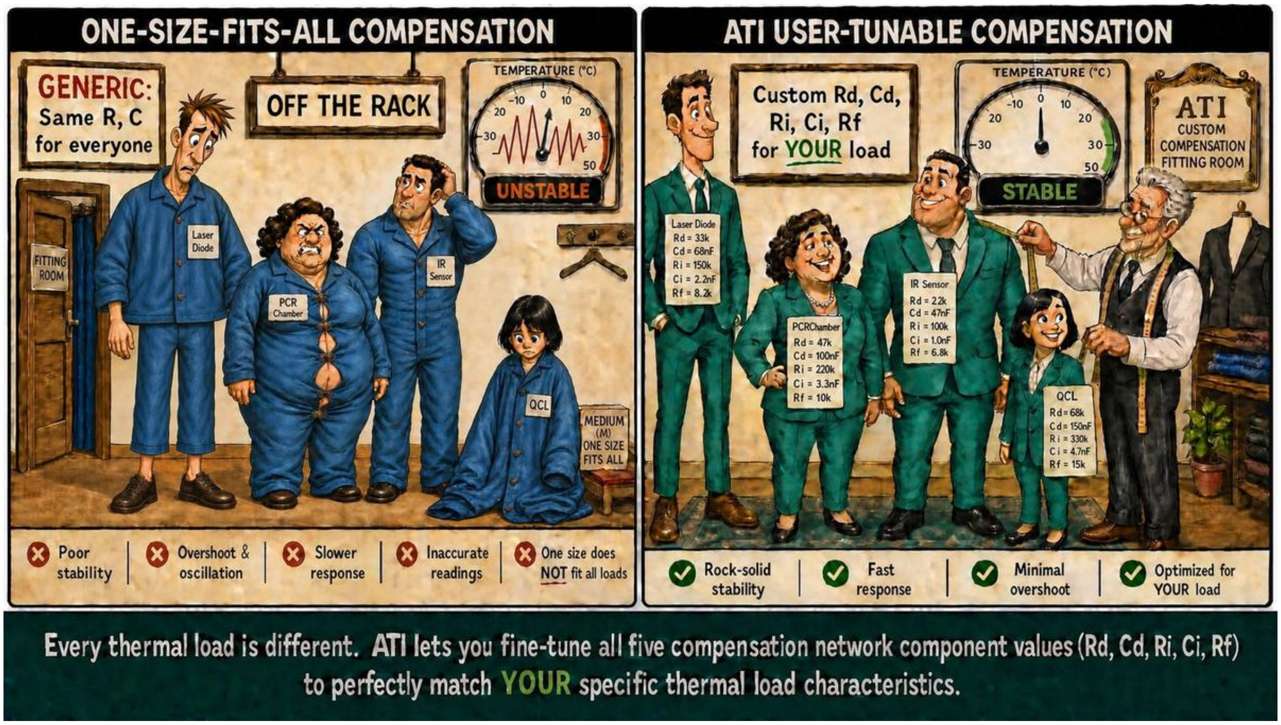


Figure 10 — The Tailor's Fitting Room. Left: one-size-fits-all compensation — every thermal load squeezed into the same ill-fitting values (oscillation, overshoot, poor stability). Right: ATI determines Rd, Cd, Ri, Ci, Rf for YOUR thermal load. Every load gets a perfect fit. *Design rule: Never use default compensation values in production — always tune to your specific thermal load.*

6.5 Evaluation Board — Fast-Track to Perfect Stability

Don't guess — measure. ATI's evaluation boards come pre-loaded with the TEC controller and a complete compensation network. Available for every controller family:

- TECEV104 — evaluates TEC5V4A, TEC5V6A, and TECA1 families
- TEC28V15AEV1/EV2 — evaluates TEC18V15A and TEC28V15A series
- TEC14MEV1.0 — evaluates Micro TEC controllers

All five components (Rd, Cd, Ri, Ci, Rf) are socketed or adjustable, so you can:

1. **Evaluate** the controller with your actual TEC and thermal load in minutes
2. **Fine-tune** each compensation value hands-on while watching the temperature response
3. **Validate** stability before committing to production values
4. **Ship** — transfer the proven values to your final PCB layout

Time saved: Weeks of breadboard guesswork → minutes of structured evaluation.

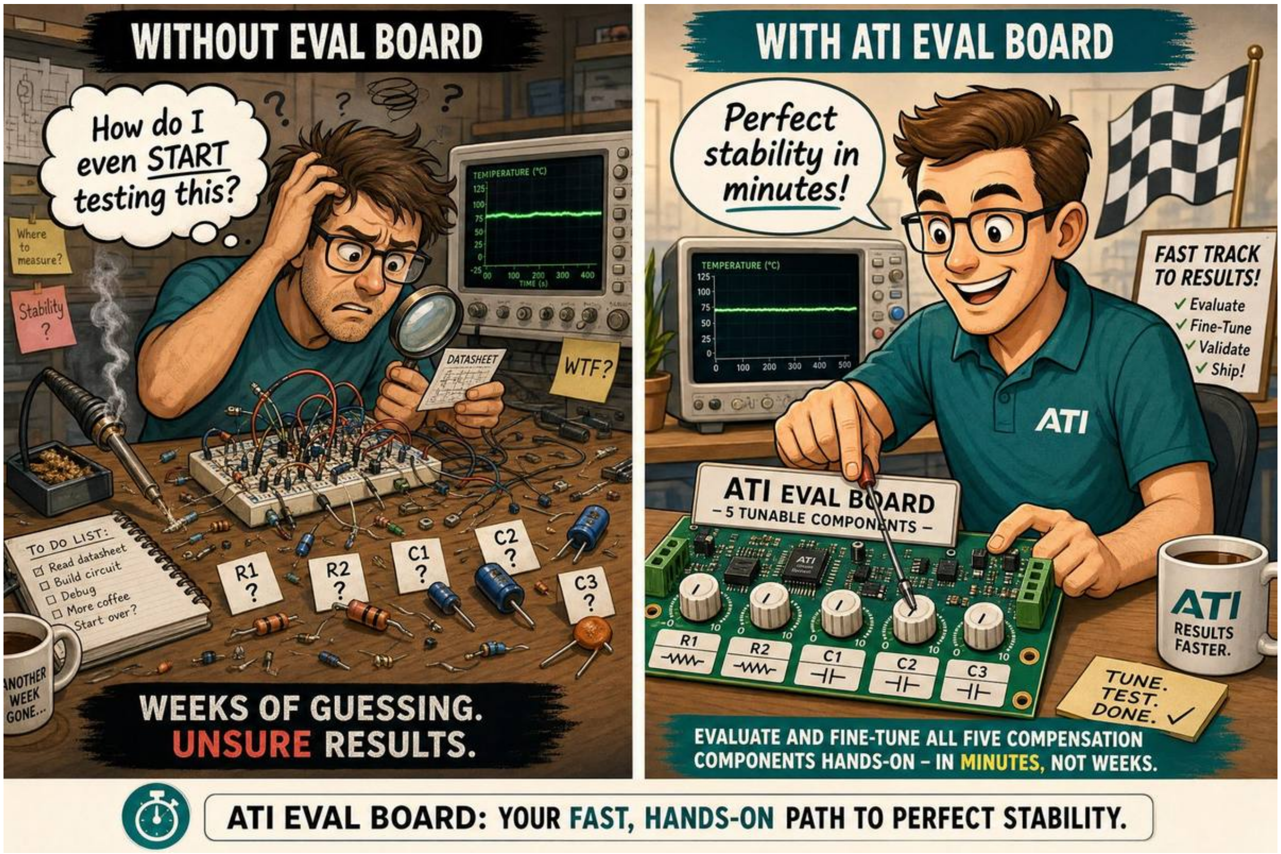


Figure 11 — Without vs. With ATI Eval Board. Left: weeks of guessing, loose components, unsure results. Right: perfect stability in minutes — evaluate and fine-tune all five compensation components hands-on. *Design rule: Always validate compensation values on the eval board before committing to production layout.*

6.6 Full Product Span — One Architecture, Every Size

ATI covers the entire range from micro to high-power: 2.7 V to 25 V input, 2.5 A to 15 A output, 14 mm to 36 mm footprint. One vendor, one design philosophy, pin-compatible upgrades within families.

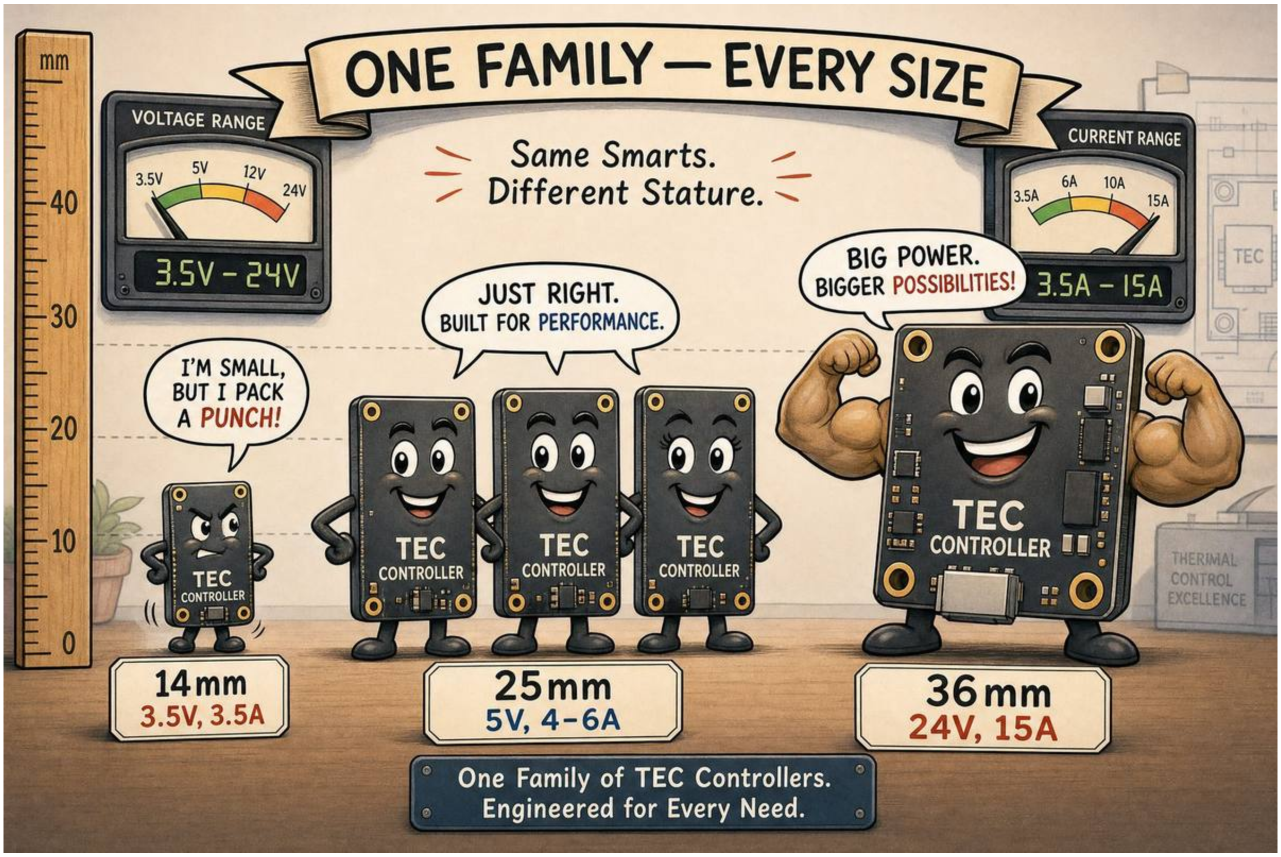


Figure 12 — One Family, Every Size. From the 14 mm micro (3.5 A, 5.5 V) to the 36 mm powerhouse (15 A, 25 V) — same precision, same shielding, same never-obsolete commitment. *Design rule: Start with the eval board for your power level; scale up or down within the ATI family without redesigning your control loop.*

6.7 Since-1997 Continuity — No Controller Discontinued to Date

- No controller model discontinued to date (every model introduced since ATI's founding in 1997 remains in active production)
- Pin-compatible upgrades — no forced redesigns
- Same-day shipping from San Jose inventory
- Direct engineering support from the circuit designers who built the product

Figure 13 — The Electronics Graveyard. Competitors' products become tombstones after 5–7 years. ATI's controllers are classics that stay in production — every model since 1997, still in stock. *Design rule: Choose a vendor whose product lifecycle matches your product's — ATI's 27+ year track record means no surprise end-of-life notices.*

7. Performance Analysis — Error Budget

A realistic error budget for a ±0.001 °C system:

Error Source	Typical Magnitude	How to Minimize
Thermistor interchangeability	±0.05–0.2 °C	Use matched precision thermistors or calibrate
Thermistor self-heating	0.001–0.01 °C	Reduce excitation current; use high-R thermistor
ADC/reference drift	±0.001–0.005 °C	ATI's internal reference is laser-trimmed
Thermal gradient (sensor to load)	0.01–0.1 °C	Mount sensor directly on load; use thermal epoxy
Ambient temperature variation	0.001–0.01 °C/ °C_ambient	Improve insulation; increase loop gain
TEC current ripple	0.0001–0.001 °C	ATI's output filter reduces ripple to <1%
Controller noise floor	<0.0005 °C	DAH-grade controllers have lowest noise
Total (RSS, well-designed system)	**±0.001–0.005 °C**	Depends on grade and thermal design

Key insight: The controller is rarely the limiting factor. Thermal interface quality, sensor placement, and heatsink design dominate the error budget. ATI's DAH-grade controllers (TEC5V6A-DAH) contribute <0.5 mV equivalent noise — the rest is up to your thermal and mechanical design.

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8. Reliability and Long-Term Stability

8.1 Thermistor Aging

NTC thermistors drift over time — typically 0.02–0.1 °C/year depending on quality and operating temperature. For long-life systems: - Use glass-encapsulated or hermetically sealed precision thermistors - Recalibrate annually for ±0.001 °C applications - Consider platinum RTDs for >10-year stability (supported by TECA1 and TEC18V15A models)

8.2 TEC Solder-Fatigue from Thermal Cycling

Every heat-cool cycle stresses the TEC's internal solder joints. Lifetime depends on ΔT per cycle and cycle count: - ΔT < 20 °C: >1 million cycles typical - ΔT = 40 °C: ~200,000 cycles - ΔT > 60 °C: <50,000 cycles

Mitigation: Operate at minimum ΔT needed. Size the TEC module so you run at 25–30% of I_max. Avoid rapid cycling between extreme temperatures.

8.3 Condensation Below Dew Point

When cooling below ambient dew point, moisture condenses on the cold surface — causing corrosion, electrical shorts, and optical contamination.

Prevention: Seal the cold zone with dry nitrogen or argon. Use hermetic packages for laser diodes. Monitor humidity. ATI controllers support condensation-prevention setpoint limits.

8.4 Derating and Thermal Management

The controller itself generates heat (P_loss = P_in × (1 − η)). At 92% efficiency driving 15 A at 12 V: P_loss ≈ 14 W. Ensure adequate airflow or heatsinking to keep the controller below its rated operating temperature. See ATI's heat sinks for mounting solutions.

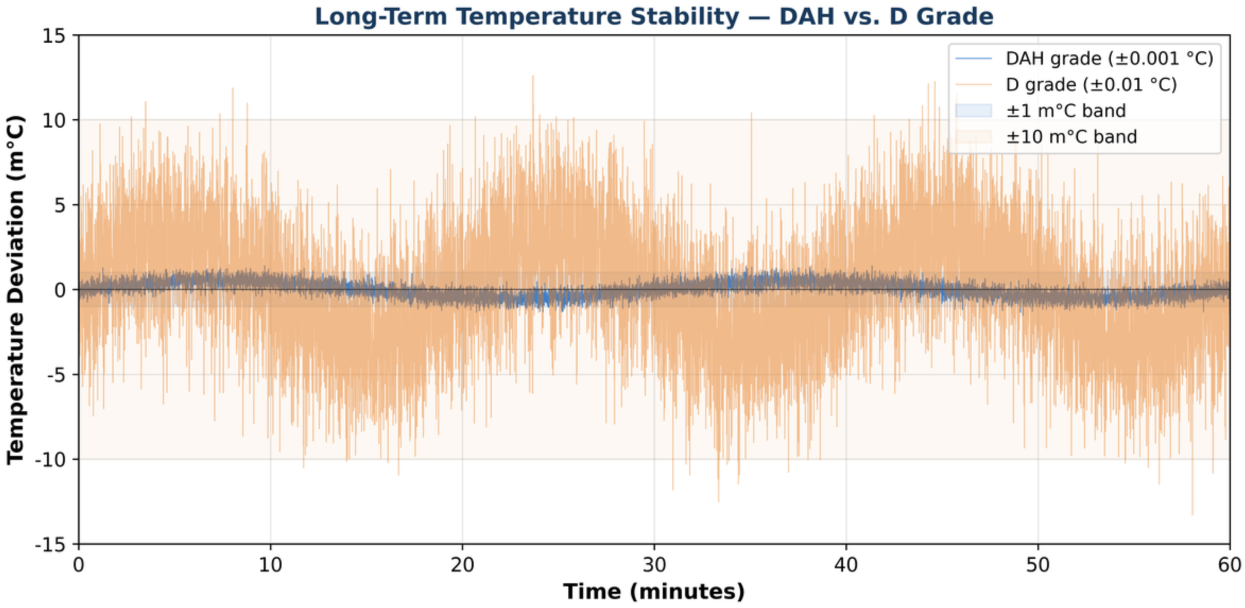

Figure 14 — Long-Term Temperature Stability: DAH vs. D Grade. 60-minute measurement comparing DAH grade (±0.001 °C, blue trace within ±1 m°C band) against D grade (±0.01 °C, orange trace within ±10 m°C band). The DAH controller maintains temperature within a 2 m°C window; the D grade shows 10× larger excursions. *Design rule: For wavelength-critical laser applications, specify DAH grade — the 10× improvement in stability directly translates to 10× tighter wavelength lock.*

9. Best Practices and Common Mistakes

Do:

- **Size TEC for 25–30% of I_max** at your operating point (maximizes COP and lifetime)
- **Mount sensor directly on the thermal load** — not on the TEC or heatsink
- **Use the evaluation board** to validate compensation before production
- **Thermally isolate** the cold side from ambient air currents

- **Use thermal interface material** between TEC and heatsink (air gaps kill performance)
- **Verify hot-side heatsink** can handle Q_h = Q_c + P_electrical at worst-case ambient

Don't:

- **Don't use default compensation values** — they're starting points, not production values
- **Don't run TEC at >50% of I_max** continuously (COP collapses, lifetime shortens)
- **Don't ignore sensor wiring** — long leads pick up noise; use shielded twisted pair
- **Don't place controller and laser driver on same unshielded PCB** — use ATI shielded modules
- **Don't cool below dew point** without moisture protection
- **Don't assume one set of compensation values works across all ambient temperatures** — verify at operating extremes or use Auto-PID

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10. Applications

TEC controllers are used wherever precise temperature stability matters:

Application	Why TEC Control?	Typical Stability	Recommended ATI Product
DFB / VCSEL laser diodes	Wavelength locks to temperature; ±0.001 °C ≈ ±0.1 pm	±0.001 °C	TEC5V6A-DAH
Photodetectors & APDs	Dark current and gain depend on temperature	±0.01 °C	TEC5V4A-DA
Optical spectrum analyzers	Grating/filter stability requires thermal lock	±0.005 °C	TECA1-xV-xV-DAH
Medical diagnostics (PCR, ELISA)	Enzyme reaction rates are temperature-critical	±0.1 °C	TEC18V15A
IR sensors & thermal cameras	Detector noise floor depends on temperature	±0.05 °C	TEC14M5V3R5AS
Semiconductor test fixtures	DUT characterization at exact temperature	±0.01 °C	TEC18V15A
Frequency references & oscillators	Crystal aging minimized at constant temperature	±0.001 °C	TEC5V6A-DAH
LiDAR transmitters	Wavelength stability for narrow-band filters	±0.01 °C	TEC5V4A-D
Quantum cascade lasers (QCL)	Mid-IR wavelength tuning via temperature	±0.005 °C	TEC18V15A
Battery testing chambers	Charge/discharge characterization at set temp	±0.5 °C	TEC18V15A
Fiber Bragg grating sensors	Wavelength shift calibration requires stable reference	±0.001 °C	TEC5V6A-DAH
CCD/CMOS cooled cameras	Dark current halves every ~7 °C of cooling	±0.1 °C	TEC5V4A-D

11. Product Selection Guide

Part Number	Input V	Max I	Size (mm)	Precision Grade	Key Feature
TEC14M5V3R5AS	2.7–5.5	3.5 A	14×14×2.2	Standard	World's smallest (to our knowledge)
TEC5V4A-D/DA/DAH	4.5–5.5	4 A	25.4×19.9×8.8	D/DA/DAH	Most popular for laser cooling
TEC5V6A-D/DA/DAH	4.5–5.5	6 A	25.4×19.9×8.8	D/DA/DAH	Higher current, same precision
TECA1-xV-xV-DAH	3.3/5.5	2.5 A	25.4×19.9×8.8	DAH	Dual input, highest precision
TEC18V15A	5.5–18	15 A	35.7×35.7×7.2	Standard	High current, ±14.5 V output
TEC18V15ADAPID	5.5–18	15 A	35.7×35.7×7.2	Standard + Auto-PID	Self-tuning, DIP
TEC28V15A	5.5–25	15 A	36.0×36.0×8.2	Standard	±20 V output, highest power
TEC28V15ASAPID	5.5–25	15 A	36.0×36.0×8.2	Standard + Auto-PID	Believed to be world's first Auto-PID module

Precision grades explained: - **D** — ≤5 mV setpoint accuracy (±0.05 °C typical) - **DA** — ≤2 mV setpoint accuracy (±0.01 °C typical) - **DAH** — ≤0.5 mV setpoint accuracy (±0.001 °C achievable under specified conditions)

Quick selection flow: Supply voltage → narrows family. Max TEC current → determines rating. Stability need → selects grade (D/DA/DAH). Variable load or field deployment → Auto-PID. See the full TEC Controller Selection Guide.

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12. Worked Example: DFB Laser at 25.000 °C

Parameter	Value	Reasoning
Target	25.000 ±0.001 °C	DFB wavelength stability requirement
Cooling load	0.8 W (laser 0.5 W + parasitics 0.3 W)	Measured with thermal test
TEC selected	ATI TEC module, I_max = 3 A	Operating at 27% of I_max
TEC operating point	0.8 A = 27% of I_max (3 A TEC)	Near COP peak
τ_th	4 s (R_th = 8 °C/W, C_th = 0.5 J/°C)	Measured step response
Hot-side dissipation	Q_h = 0.8 + 1.0 = 1.8 W	Must size heatsink for this
Crossover frequency	f_c = 0.025–0.05 Hz	f_c = 1/(5–10 × τ_th)
Controller	**TEC5V6A-DAH**	6 A max, DAH grade for ±0.001 °C
Sensor	**ATI precision NTC**	10 kΩ at 25 °C, ±0.1% tolerance

Compensation values (validated on TECEV104 eval board):

Component	Value	Rationale
Rd	100 kΩ	Sets derivative gain for τ_th = 4 s
Cd	330 pF	Derivative time constant ≈ 33 µs
Ri	470 kΩ	Integral gain — eliminates offset without oscillation
Ci	10 nF	Integral time constant ≈ 4.7 s (matches τ_th)
Rf	47 kΩ	Overall gain — provides >45° phase margin

Result: Measured stability ±0.0008 °C over 24 hours in a lab environment at 23 ±2 °C ambient. Wavelength stability: ±0.08 pm (DFB coefficient 0.1 nm/°C × 0.0008 °C = 0.00008 nm = 0.08 pm).

13. Troubleshooting Quick-Reference

Symptom	Likely Cause	Fix
Oscillation (20–60 s period)	Compensation mismatch (f_c too high)	Reduce Rf; increase Ri; or use Auto-PID
Steady-state offset (0.1–1 °C)	Insufficient integral gain	Increase Ci or decrease Ri
Overshoot >10% on setpoint change	Derivative too low or gain too high	Increase Rd; reduce Rf
Slow drift over hours	Sensor aging or ambient change	Recalibrate; improve thermal isolation
Output saturates (no regulation)	TEC undersized or heatsink failure	Larger TEC module; better heatsink
High-frequency noise on TEMP	External EMI coupling	Use ATI shielded controller; shield sensor wires
Works at 25 °C, oscillates at −20 °C	τ_th changes with temperature	Retune at operating extremes; or use Auto-PID
Condensation on cold surface	Cooling below dew point	Seal with dry gas; add dew-point setpoint limit
TEC current correct but no cooling	TEC degradation (solder fatigue)	Replace TEC module; check thermal cycling history

14. Complementary Products

ATI provides a complete thermal management ecosystem:

Product Category	What It Does	Link
TEC Modules	The thermoelectric cooler itself — various sizes and cooling capacities	TEC modules
Precision Thermistors	NTC sensors for high-accuracy temperature measurement	Thermistors
Laser Drivers	Constant-current sources for laser diodes — often co-located with TEC controllers	Laser drivers
TEC + Laser Combo	Integrated TEC + laser driver in one module	Combo controllers
Thermal Conductive Materials	Interface pads and adhesives for optimal heat transfer	Thermal materials
Heat Sinks	Aluminum and copper heatsinks for hot-side dissipation	Heat sinks
High-Voltage Power Supplies	For applications requiring >24 V (piezo, APD, PMT)	HV supplies
Evaluation Boards	Pre-built test platforms for every controller family	TECEV104
SMT Component Kits	Resistor and capacitor kits for compensation network prototyping	SMT kits

15. FAQ

Q1. What is the difference between a TEC controller and a TEC driver?

A TEC controller is a closed-loop system that automatically reads temperature and adjusts TEC current to maintain a setpoint. A TEC driver is open-loop — it delivers a commanded current without temperature feedback. Controllers are used when temperature accuracy matters; drivers are used when external logic handles the feedback.

Q2. Can ATI TEC controllers both heat and cool?

Yes. All ATI TEC controllers are bidirectional — they automatically reverse current direction to heat or cool as needed to reach the setpoint. No external switching is required.

Q3. What stability can I achieve?

±0.001 °C is achievable with DAH-grade controllers (e.g., TEC5V6A-DAH) under specified test conditions: load-matched compensation, precision thermistor, adequate thermal isolation, and stable ambient.

Q4. When should I use Auto-PID vs. manual tuning?

Use Auto-PID (TEC18V15ADAPID or TEC28V15ASAPID) when the thermal load varies between units, the operating range is wide, or tuning time is critical. Use manual tuning with the eval board for fixed-load production where you want the lowest possible noise.

Q5. How does ATI achieve zero EMI?

Full metal enclosure (all six sides) blocks capacitive, inductive, radiated, and conducted coupling. The shielding is bidirectional — protects both the controller from external noise and external circuits from controller switching noise.

Q6. What input voltage range is available?

2.7–25 V across the family. Micro TEC: 2.7–5.5 V. TEC5V series: 4.5–5.5 V. TEC18V15A: 5.5–18 V (output ±14.5 V). TEC28V15A: 5.5–25 V (output ±20 V).

Q7. What temperature sensors are supported?

NTC thermistors (default, highest resolution near 25 °C), platinum RTDs (best long-term stability), and semiconductor temperature ICs. Sensor type selection depends on the model.

Q8. Has ATI ever discontinued a TEC controller?

No. Every TEC controller model introduced since ATI's founding in 1997 remains in active production and available for purchase. No forced redesigns due to end-of-life.

Q9. How do I choose compensation values (Rd, Cd, Ri, Ci, Rf)?

Measure your thermal load's time constant τ_th (step response test). Set crossover frequency f_c = 1/(5–10 × τ_th). Use the evaluation board to iterate component values while monitoring temperature response. ATI's datasheets provide starting-point tables.

Q10. What comes with the evaluation board?

The controller module, compensation network (all 5 components socketed/adjustable), TEC connector, thermistor input, power terminals, and test points. Plug in your TEC and thermal load, connect power, and begin tuning immediately.

Q11. What is the precision grade difference (D vs. DA vs. DAH)?

D = ≤5 mV setpoint accuracy. DA = ≤2 mV. DAH = ≤0.5 mV. Higher grades use tighter-tolerance internal components and lower-noise references. Choose based on your stability requirement.

Q12. Can I use ATI controllers for Peltier heating only (no cooling)?

Yes. Set the setpoint above ambient and the controller drives current in the heating direction. All models support heating-only, cooling-only, or bidirectional operation.

Q13. How do I prevent condensation when cooling below dew point?

Seal the cold zone in a hermetic or dry-gas-purged enclosure. Use desiccant if the enclosure is not perfectly sealed. Set a minimum temperature limit in your control logic to prevent cooling below the local dew point.

Q14. What is the maximum TEC current available?

15 A from the TEC18V15A series. For higher currents, contact ATI engineering for custom solutions or parallel configurations.

Q15. Where can I buy ATI TEC controllers?

Direct from ATI: online store, email sales@analogtechnologies.com, or phone 408-748-9100. Same-day shipping available from San Jose inventory.

16. Design Resources

Resource	Link
TEC Controller Selection Guide	Selection Guide
Design Notes (TEC controllers)	Design Notes
All White Papers	White Papers
Request a Quote (RFQ)	Contact ATI
Online Store	shop.analogtechnologies.com

17. References

[1] Analog Technologies, Inc. "TEC Controller Product Family." www.analogtechnologies.com.

[2] G. Liu, "Thermoelectric Cooler Controller," U.S. Patent 6,486,643 B2, issued Nov 26, 2002. Assigned to Analog Technologies, Inc.; licensed to Analog Devices, Inc. for TEC controller ICs.

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[4] Analog Technologies, Inc. "TEC Modules." www.analogtechnologies.com.

[5] Analog Technologies, Inc. "Precision Thermistors." www.analogtechnologies.com.

[6] Analog Technologies, Inc. "Evaluation Board TECEV104." www.analogtechnologies.com.

[7] Analog Technologies, Inc. "TEC Controller Selection Guide." www.analogtechnologies.com.

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