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What Is a Laser Driver?

A Practical Guide to CC/CP Control, Protection, Low-Noise Design, Modulation, Monitoring, and PWM Efficiency · Rev. 1.0 · June 2026

Abstract

A **laser driver** is the precision electronics that stand between a power supply and a laser diode, converting a command into a clean, regulated, protected drive. This paper explains what a laser driver does, why a laser diode must be driven by controlled current rather than raw voltage, how the main functional blocks work from first principles, and how to select the right driver for an application. It connects each design concern to verified product features from the Analog Technologies, Inc. (ATI) laser-driver families — including the ultra-low-noise ATLSxA103 series (100 mA to 1 A), the high-efficiency ATLSxA201D series, and the synchronizable ATLSxA202D series. **Key takeaway:** choosing a laser driver is not about peak current; it is about delivering the correct current under real system conditions while protecting the diode and reporting its status.

Executive Summary

A laser diode is small but unforgiving: a brief current transient can destroy a part that costs far more than the driver. Engineers must decide several things before buying anything — whether to regulate current (CC) or optical power (CP), how much current noise the optical system can tolerate, how much voltage headroom (compliance) the diode needs, whether high efficiency or lowest noise matters more, and what protection and monitoring the larger instrument requires.

This paper helps make those decisions with first-principles theory, tradeoff tables, a worked numerical example, and a product-selection guide. Throughout, ATI product advantages are stated only with verified evidence: low noise, high stability, high efficiency, compact shielded packaging, full protection, and real-time current and optical-power monitoring.

> **One-sentence definition.** *A laser driver is a precision current-control or optical-power-control circuit that delivers a clean, regulated drive to a laser diode while managing startup, shutdown, noise, modulation, monitoring, temperature, and fault protection.*

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1. Introduction: Why a Laser Diode Needs a Driver, Not a Voltage Source

A laser diode is a current-operated semiconductor device. Once it is forward biased past threshold, a small change in voltage produces a large change in current, and a large current transient can destroy the junction faster than a person can blink. For that reason a laser-diode driver is fundamentally a controlled current source (or optical-power loop), not a voltage supply.

A bench supply has power, but power alone is not enough; the diode needs the right current at the right time, with the right noise level, under the right temperature and protection conditions.

Ordinary power-source behavior	What a laser diode actually needs
Regulates voltage; current depends on the load.	Regulates current (or optical power) so output is predictable.
May overshoot at turn-on, load change, or hot-plug.	Starts and stops softly, without spikes.
Passes supply ripple, EMI, and ground noise to the load.	Rejects supply, ground, and control-signal noise.
Does not know whether the laser is overheating or open.	Monitors current, temperature, and fault status.
Efficient only under some load conditions.	Stays efficient, especially for high-current PWM designs.

1.1 Why Constant Current, Not Constant Voltage?

A laser diode's forward voltage (Vf) is not fixed — it drifts with temperature at approximately −2 mV/°C (typical for GaAs- and InP-based diodes; GaN-based diodes may differ). This drift is caused by the temperature dependence of the semiconductor bandgap and is clearly documented in every laser diode datasheet.

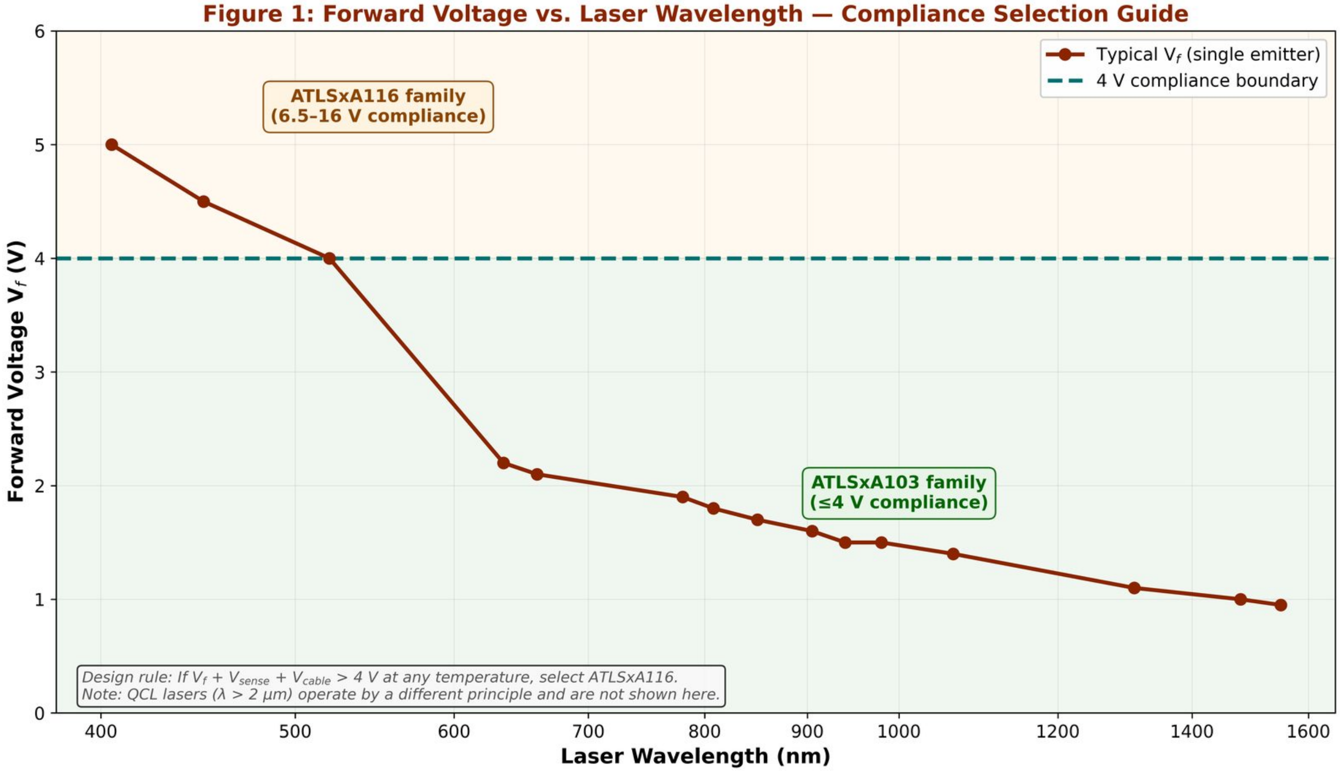
Under **constant voltage (CV) mode**, if the supply voltage is fixed and Vf changes with temperature, the current through the diode changes too. Since optical power is directly proportional to current above threshold, the optical output becomes unstable — it fluctuates with every temperature variation.

Under **constant current (CC) mode**, the driver forces a fixed current regardless of Vf drift. The driver automatically adjusts its output voltage to accommodate the changing load voltage, keeping the current — and therefore the optical power — rock-steady at constant temperature.

This is why virtually all professional laser systems use CC mode (or CP mode with current feedback underneath). Driving a laser diode with a constant voltage source is fundamentally incompatible with stable optical output.

1.2 Forward Voltage vs. Laser Wavelength: Why Compliance Voltage Depends on Your Laser

Different laser diode types operate at different forward voltages because Vf is fundamentally tied to the semiconductor bandgap energy — and bandgap determines emission wavelength. Shorter wavelengths require wider bandgaps and therefore higher forward voltages. This relationship has a direct, practical consequence for driver selection: the compliance voltage required depends on which laser you are driving.



Design rule: If $V_f + V_{sense} + V_{cable} > 4$ V at any temperature, select ATLSxA116.
Note: QCL lasers (λ > 2 µm) operate by a different principle and are not shown here.

Figure 1. Typical forward voltage vs. emission wavelength for common laser diode types. Shorter wavelengths (UV, blue, green) require wider-bandgap materials with higher Vf (3–5 V), while longer wavelengths (near-IR, telecom, mid-IR) use narrower-bandgap materials with lower Vf (1–2 V). Quantum cascade lasers (QCLs) in the mid-IR to THz range operate at 8–15 V due to their multi-quantum-well cascade structure. *Design rule:* always check your laser's maximum Vf at the lowest operating temperature (where Vf is highest) and select a driver with sufficient compliance margin.

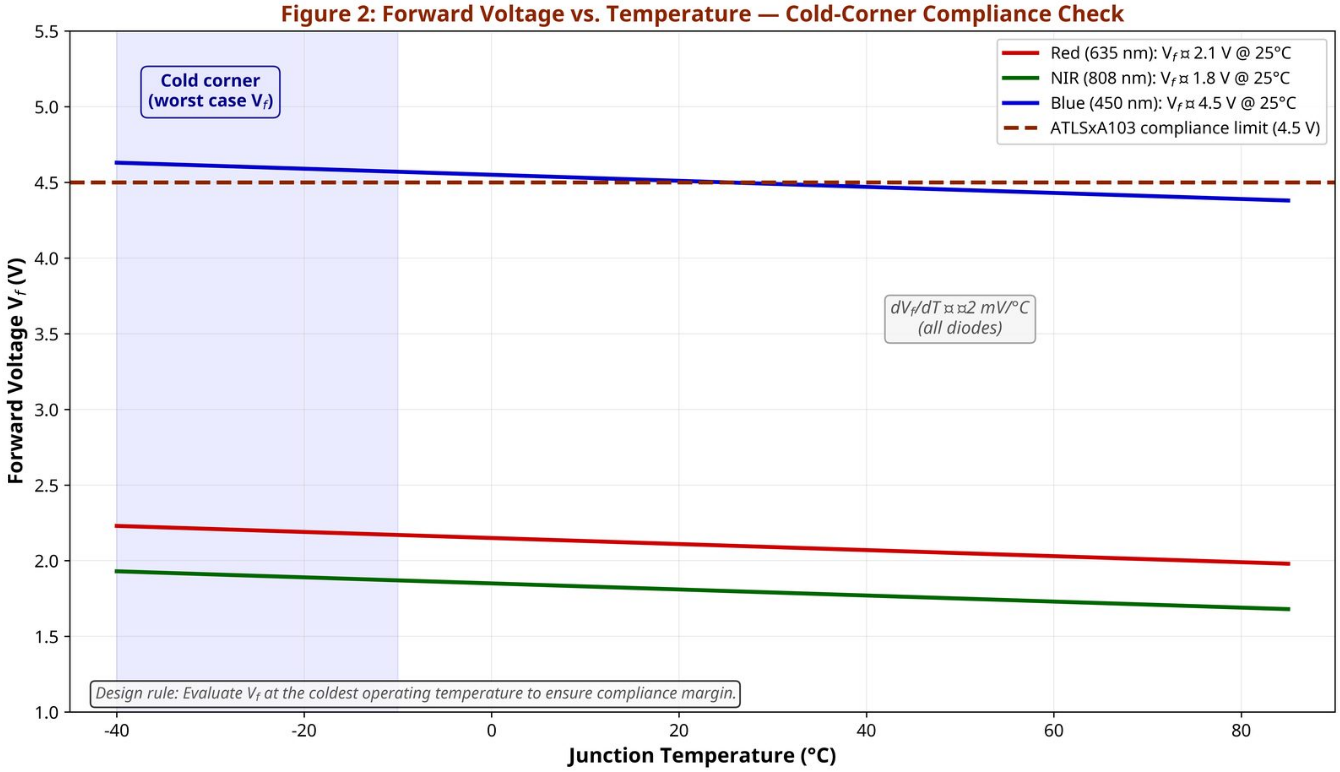


Figure 2. Forward voltage versus junction temperature for representative diodes. Vf falls at roughly −2 mV/°C, so **Vf is highest at the lowest operating temperature** — the worst case for compliance. A 5 V linear stage (ATLSxA103) provides approximately 4.5 V of usable compliance after sense-resistor and cable drops; the blue diode exceeds this and therefore requires the high-compliance ATLSxA116. *Representative values — confirm against the diode datasheet.*

The table below summarizes typical forward voltages by laser type:

Laser Type	Wavelength Range	Typical Vf	Material System	Recommended ATI Driver
UV laser diode	375–405 nm	4.5–5.5 V	GaN/AlGaN	ATLSxA116 (high compliance)
Blue laser diode	405–470 nm	4.0–5.0 V	InGaN/GaN	ATLSxA116 (high compliance)
Green laser diode	510–535 nm	4.5–6.0 V	InGaN	ATLSxA116 (high compliance)
Red laser diode	630–680 nm	2.0–2.5 V	AlGaInP	ATLSxA103 (standard)
Near-IR laser diode	780–980 nm	1.5–2.0 V	GaAs/AlGaAs/ InGaAs	ATLSxA103 (standard)
Telecom laser diode	1310–1550 nm	1.0–1.5 V	InGaAsP/InP	ATLSxA103 (standard)
Quantum cascade laser (QCL)	3–12 µm	8–15 V	InGaAs/AlInAs	AQCL series (high compliance, linear)

Key insight: For standard near-IR and telecom diodes (Vf ≤ 2.5 V), the ATLSxA103 series with a 5 V supply provides ample compliance headroom. For blue, green, and UV diodes (Vf > 4 V), or for QCLs (Vf = 8–15 V), the ATLSxA116 series (6.5–16 V input) or AQCL series (10–28 V input) is required to maintain regulation. Always calculate compliance at the lowest operating temperature, where Vf is at its maximum.

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2. Fundamental Theory: Commanding, Sensing, and Correcting Current

In a feedback laser driver, a control voltage sets a desired current, a sense element measures the actual current, and an error amplifier drives the output stage until the two agree. The first-order relationship is simply Ohm's law across the sense resistor:

$$I\_LD = V\_CTRL / R\_SENSE$$

Here I_LD is the laser current (amperes), V_CTRL is the control or setpoint voltage (volts), and R_SENSE is the current-sense resistance (ohms). The equation is intentionally simple: it captures the principle that current is commanded, measured, and corrected. Real drivers add loop compensation, compliance-voltage limits, protection logic, filtering, and layout-dependent parasitics on top of it.

Two consequences matter at the bench. **First, compliance voltage** — the output voltage the driver can develop — must exceed the laser forward voltage plus the sense-resistor drop plus any cable drop, or the loop saturates and cannot reach the commanded current:

$$V\_COMPLIANCE \geq V\_f(max) + I\_LD \times R\_SENSE + V\_CABLE$$

When the required compliance exceeds approximately 4 V — for example, with quantum cascade lasers (QCLs), series-connected diode stacks, or high-Vf UV/blue diodes — the standard ATLSxA103 series (5 V input) cannot provide sufficient headroom. For these applications, ATI’s ATLSxA116 series accepts 6.5–16 V input and delivers higher compliance voltage with the same ultra-low noise philosophy (300 nAp-p output noise), making it the natural choice for high-Vf laser loads. ATI’s compliance-voltage maximization topology is protected under U.S. Patent 6,879,608.

Second, because current is set through R_SENSE, the thermal noise of that resistor contributes directly to the current-noise floor. The Johnson noise voltage across the sense resistor is:

$$V\_n = \sqrt{4\ k\ T\ R\_SENSE\ \Delta f}$$

where k is Boltzmann’s constant (1.38×10^{-23} J/K), T is absolute temperature, and Δf is the measurement bandwidth. This noise voltage divides by R_SENSE to become a current-noise contribution: $I_n = V_n / R_{SENSE} = \sqrt{4kT\Delta f / R_{SENSE}}$. A larger R_SENSE lowers the current-noise contribution and improves setpoint resolution, but costs voltage headroom (less compliance) and more dissipation. A smaller R_SENSE preserves headroom but raises the relative current noise and demands a more precise, low-noise reference. These two facts — not peak current — decide whether a driver will actually work in your system.

2.1 High Rejection to Load Variation

A well-designed CC laser driver exhibits high rejection to load variation — meaning that even as the laser diode's forward voltage changes (due to temperature, wavelength shift, or aging), the output current remains virtually unchanged. This is analogous to a metered water pump that delivers exactly the same flow rate regardless of whether the pipe downstream gets narrower or wider.

ATI laser drivers achieve this through precision error-amplifier design with high loop gain, ensuring that load-voltage perturbations are rejected by 60 dB or more (typical, within the control bandwidth).

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3. System Architecture: How the Driver Fits the Instrument

A practical laser driver is more than a current source. It combines CC/CP regulation, soft start and soft turn-off, low-noise design, supply and thermal protection, modulation, monitoring, photodiode feedback, shutdown control, and loop compensation, so the diode receives controlled current or controlled optical power without dangerous surprises.

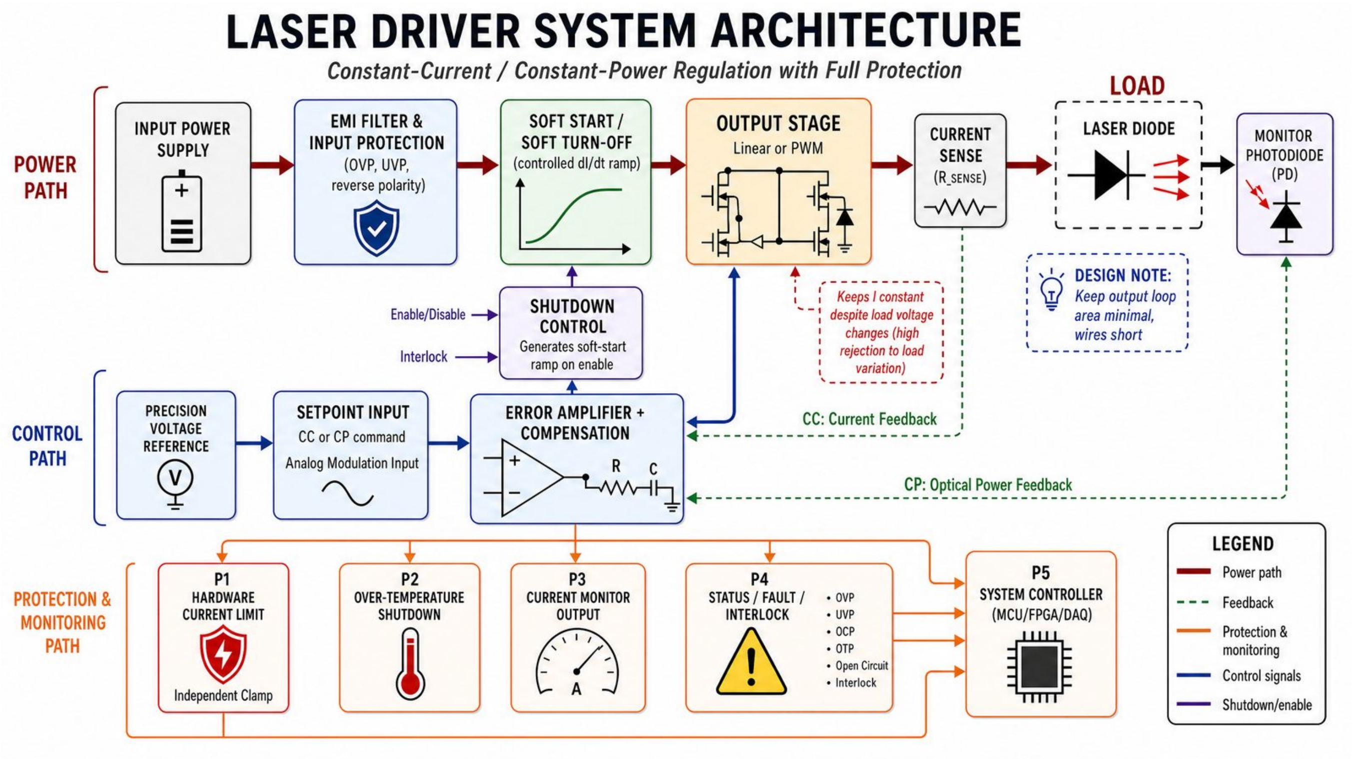

Figure 3. Laser-driver system architecture. The power path (dark red) runs input supply → EMI filter and input protection → soft start/soft turn-off → output stage (linear or PWM) → current sense → laser diode and monitor photodiode. The control path (blue) runs precision voltage reference → setpoint input → error amplifier with compensation → output stage. Feedback paths (green dashed) close the loop: CC feedback from the current sense, CP feedback from the monitor photodiode. The shutdown control block (purple) receives enable/disable and interlock signals and generates the soft-start ramp on enable. The protection and monitoring path (orange) includes hardware current limit, over-temperature shutdown, current monitor output, and status/fault/interlock — all reporting to the system controller (MCU/FPGA/DAQ).

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4. Operating Modes: CC vs CP — Which One and Why?

A laser driver can regulate in **constant-current (CC)** mode, **constant-power (CP)** mode, or a controlled combination. In CC mode the driver holds laser current constant; optical power then depends on the diode, temperature, aging, and optical coupling. In CP mode the driver uses a monitor photodiode to adjust current so that measured optical power stays constant. **CC defines and limits electrical stress; CP stabilizes light output.**

Figure 4. CC mode is like locking the gas pedal at one position — the car's speed (optical power) varies as the road changes (temperature, aging). Going uphill the car slows to 20 MPH; downhill it rockets to 90 MPH. CP mode is like cruise control — the speed is locked at 65 MPH and the gas pedal moves automatically to maintain it regardless of road conditions. *Design rule:* in CP mode the current can climb to hold power as the diode ages or heats, so a current limit must stay active underneath the optical loop.

An analog input can modulate either philosophy: in CC mode it modulates the current command; in CP mode it modulates the optical-power setpoint. Some systems use alternating CP/CC: CP at low optical power for light stability, switching to CC at high current so the current stays limited and predictable.

Mode	Held constant	Feedback	Best for	Practical caution
CC — constant current	Laser current	Current sense	Predictable electrical stress, current-limited operation	Optical power drifts with temperature, aging, coupling
CP — constant power	Optical power	Monitor photodiode	Stable light output; instruments that care about emitted power	Current can rise to hold power unless limiting/thermal protection is correct
Alternating CP→CC	Power at low level; current at high level	Photodiode then current	Low-power optical stability with high-current safety	Transition must be stable and documented

4.1 Why Most Laser Systems Choose CC Mode

CC mode has a fundamental advantage over CP mode in many real-world optical systems: **the feedback sensor cannot be fooled.**

In CP mode, the monitor photodiode measures "optical power" — but it cannot distinguish between the actual laser output, back-reflections returning from the optical path (lenses, fibers, mirrors), and ambient or stray light leaking into the detector. When these unwanted signals reach the photodiode, the controller over-corrects based on corrupted data: it reduces current when stray light makes the reading too high, or increases current when reflections disappear — causing the real laser power to fluctuate unpredictably.

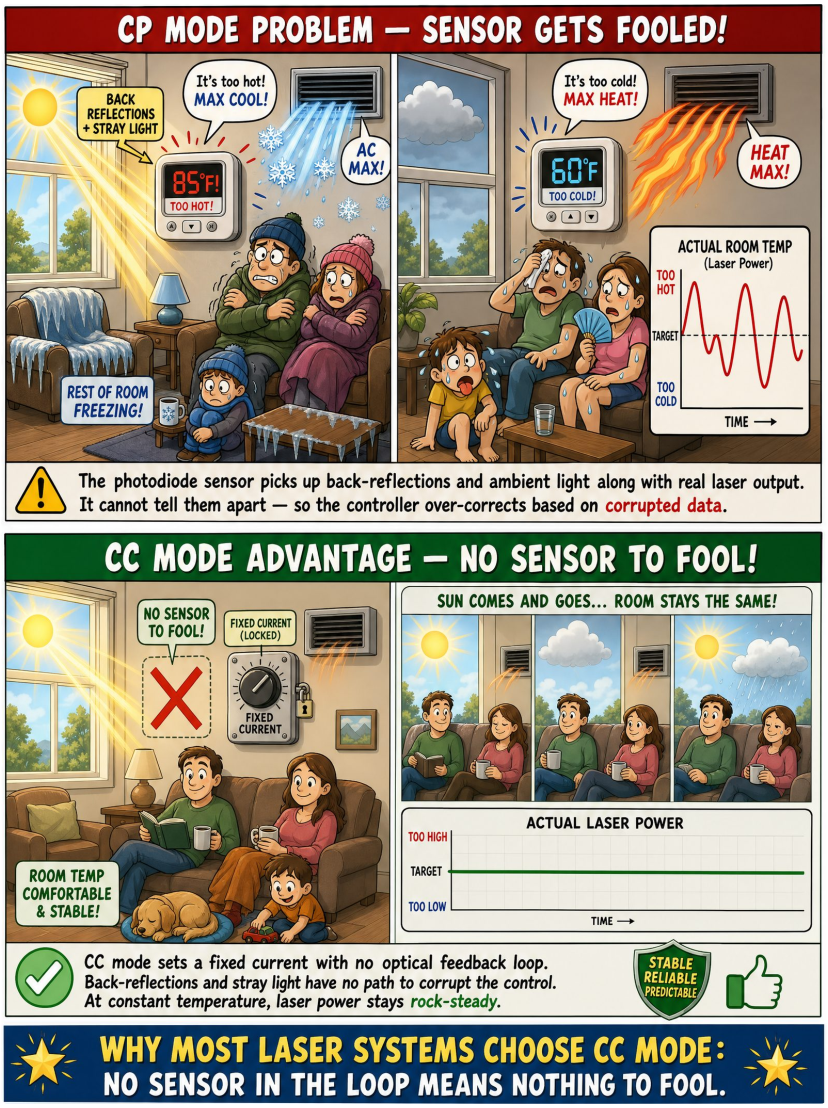

Figure 5. The thermostat analogy: In CP mode (top), sunlight streaming through a window (= back-reflections + stray light) heats the thermostat sensor — it reads 85°F and blasts the AC, freezing the room. When clouds pass, it reads 60°F and blasts the heater. The actual room temperature (laser power) oscillates wildly. In CC mode (bottom), there is no sensor in the loop to fool. A fixed heater output (= fixed current) keeps the room comfortable regardless of whether the sun comes and goes. *Key insight:* CC mode sets a fixed current with no optical feedback loop. Back-reflections and stray light have no path to corrupt the control. At constant temperature, laser power stays rock-steady.

5. Design Considerations and Protection

5.1 Soft Start: Why the First Milliseconds Matter

Soft start controls the current ramp at turn-on. Without it, supply rise time, reference settling, loop acquisition, and output capacitance can produce transient current pulses; a pulse that is electrically brief can still be optically or thermally destructive.

Figure 6. Soft start is like accelerating a car from a stop. Without soft start (left): the driver floors the gas pedal at the green light — passengers' heads snap backward into the headrest, coffee flies everywhere, neck whiplash. The current waveform shows an instant spike. With soft start (right): the driver eases onto the gas gently — passengers sip coffee peacefully, heads stay upright, smooth comfortable ride. The current waveform shows a controlled ramp. *Design rule:* treat turn-on behavior as a protection feature, not a convenience. Soft start protects your laser diode — smoother drive, longer life.

Startup behavior is a protection feature, not a convenience. ATI's high-efficiency ATLSxA201D constant-current laser drivers are an upgraded drop-in replacement for the earlier CWD-01-V2 modules, with a much shorter startup time — on the order of 4 ms versus about 100 ms — while keeping high-efficiency CC operation.

5.2 Soft Turn-Off: The Last Impression Matters

Shutdown can be as dangerous as startup. Energy stored in inductance, capacitance, cables, and the output stage can produce a final spike if the driver turns off abruptly. Soft turn-off lowers current in a controlled way so the diode never sees a parting pulse. The shutdown control block in ATI drivers manages both the soft-start ramp on enable and the controlled ramp-down on disable, ensuring the laser diode is never subjected to transient stress at either transition.

5.3 Hardware Current Limit: The Safety Net Many Drivers Lack

An independent hardware current limit is the last line of defense for a laser diode. Even if the user accidentally sets the current too high, the control loop malfunctions, a software glitch sends the wrong DAC value, or the photodiode fails in CP mode — the hardware current limit intervenes and prevents the laser from being destroyed.

Many laser-driver ICs do not include an independent hardware current limit. High-speed telecom and datacom drivers often prioritize modulation bandwidth and may not provide a current limit separate from the set-point — always verify this on any candidate part. When a limit is present, it may either clamp the current at the limit value or shut the driver down and safely restart; both are valid protection strategies, but the key requirement is that the limit exists and operates independently of the control loop. If no independent limit is present and the control loop malfunctions, software sends the wrong DAC value, or the photodiode fails in CP mode, nothing stops the overcurrent from destroying the laser diode.

Figure 7. The guardrail analogy: Without a current limit (left), the car labeled "LASER CURRENT" loses control and flies off the cliff — the current shoots past I_max with nothing to stop it. Destroyed laser diode, thousands of dollars lost. With ATI's independent hardware current limit (right), the same loss of control hits the guardrail — the driver shuts down safely and automatically restarts once conditions are safe. *Design rule:* always verify that your laser driver has an independent hardware current limit separate from the set-point — it is the difference between a recoverable fault and a destroyed diode.

ATI laser drivers include an independent, user-adjustable hardware current limit (the LILM port on the ATLSxA103 series) across all families. When the output current reaches the user-set limit, the driver shuts down, waits, and then safely restarts. This limit operates independently of the CC or CP control loop and provides absolute protection regardless of the failure mode.

5.4 Supply Over- and Under-Voltage Protection

Input supplies ring during hot-plug, dip during load changes, and overshoot at startup. Under-voltage protection prevents "half-awake" behavior when references, amplifiers, and logic are not yet fully controlled; over-voltage protection prevents overstress of the driver and the diode. These checks are an aircraft preflight checklist: if conditions are wrong, the system should not take off.

5.5 Compact Output-Loop Layout

The high-current loop from LDA, through the laser diode, and back to LDC must be short and physically tight. As a practical rule, keep the laser wires as short as possible (under 10 cm; shield any connection longer than 5 cm) and the LDA → laser → LDC loop area below about 5 cm². A large loop behaves like a one-turn antenna and an unwanted inductor: it radiates switching energy, picks up EMI, and creates ringing during fast current changes.

Figure 8. Output-loop layout: a short, tidy racetrack (loop area <5 cm², wires <10 cm) stays quiet, while a long wandering loop becomes an antenna for ringing and EMI. *Design rule:* route the outgoing (LDA) and return (LDC) conductors together to minimize enclosed area.

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6. Engineering Challenges: Linear vs PWM, and the Beat-Frequency Trap

A linear output stage is quiet but dissipates heat when the voltage drop across it is large. A PWM (switching) stage is far more efficient and runs cooler, enabling compact high-current designs, but it must be managed for EMI, ripple, synchronization, filtering, and layout.

Design emphasis	Typical advantage	Design challenge
Linear low-noise driver	Very low ripple, simpler noise behavior	Higher heat at large voltage drop
PWM / switching high-current driver	High efficiency, lower heat, compact	EMI, filtering, synchronization, layout

Design emphasis	Typical advantage	Design challenge
Synchronizable switching driver	Reduces beat interference among switchers	Requires system clock planning

One subtle PWM mistake deserves special attention. If the laser-driver PWM frequency sits too close to the power-supply switching frequency, the two systems create a low beat frequency near their difference. A low beat is much harder to filter than the original high-frequency ripple and can leak into the laser current as optical modulation.

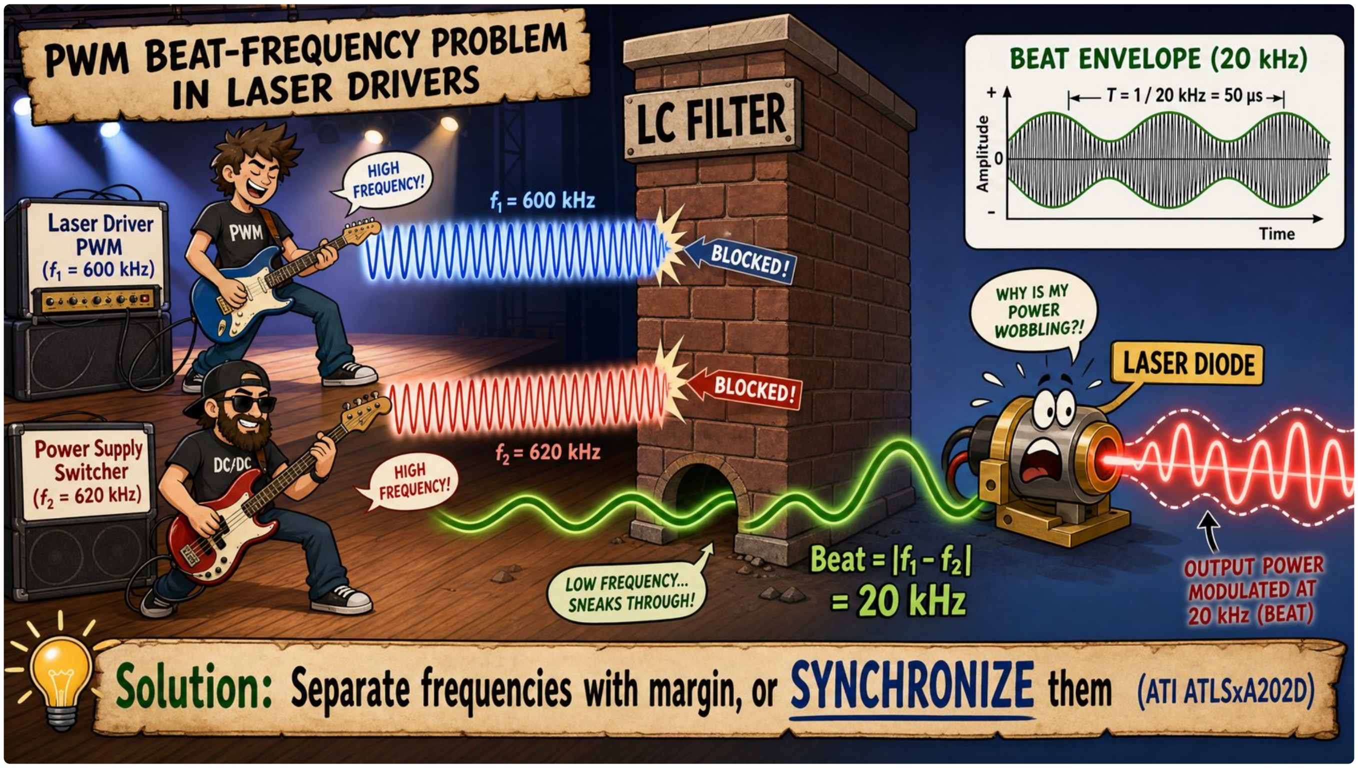

Figure 9. PWM beat frequency: two nearly-in-tune switchers ($f_1 \approx f_2$) produce a slow beat at $|f_1 - f_2|$ that slips past filtering into the laser current. The high-frequency individual waves are blocked by the LC filter, but the slow envelope (beat) sneaks through to modulate the laser. *Design rule:* separate the two switching frequencies with margin, or synchronize them.

For boards with multiple switchers, ATI's ATLSxA202D constant-current laser drivers provide a frequency-synchronization function: an external digital signal in the 520–800 kHz range synchronizes the driver's internal PWM stage, eliminating beat interference with other switch-mode circuits on the PCB. Compare datasheet switching frequencies early, separate them with margin, and verify laser-current ripple under real supply conditions.

6.1 How to Choose Between a Linear Driver and a PWM Driver

The decision between linear and PWM topology comes down to current level, noise sensitivity, efficiency requirements, and the optical system's loop bandwidth.

General guidelines:

Criterion	Choose Linear	Choose PWM
Output current	≤ 500 mA to 1 A	> 1 A
Noise priority	Lowest possible current noise	Noise is acceptable or filtered by system
Efficiency priority	Acceptable (moderate dropout)	Critical — must minimize heat
Thermal budget	Adequate heatsinking available	Tight thermal envelope, compact enclosure

When noise is the primary concern, a linear driver is the natural choice. It has no switching frequency, no ripple tones, and no EMI from fast edges. The ATLSxA103 series achieves output current noise as low as 1.5 µAp-p (0.1–10 Hz on the 100 mA variant) — performance that no PWM driver can match without extensive external filtering.

When efficiency is the primary concern, or when the laser requires high current (above 1 A), a PWM driver becomes necessary. Linear drivers at high current dissipate significant heat across the pass element (P_dissipated = I_LD × (V_supply − V_f − V_sense)), which can exceed the thermal budget of a compact instrument.

The important nuance: PWM is not always noisy. Many laser applications operate in CW (continuous-wave) mode with a very slow system loop response. A prime example is pump lasers for erbium-doped fiber amplifiers (EDFA). In an EDFA, the system control loop bandwidth is typically only a few Hz to a few hundred Hz — far below the PWM switching frequency (hundreds of kHz to MHz). The high-frequency PWM ripple is completely invisible to the EDFA loop because the amplifier's gain medium integrates over milliseconds. The EDFA only "sees" the average optical pump power, not the fast ripple riding on top of it.

For these slow-loop CW applications — EDFA pumping, Raman amplification, thermal processing, and similar systems where the optical detector or control loop cannot respond to high-frequency content — a PWM laser driver is a perfect fit. It delivers high current efficiently with low heat, and the switching ripple is irrelevant to system performance.

Decision summary:

- Low current (≤ 500 mA to 1 A) + low noise required → **Linear** (ATLSxA103 series)
- High current (> 1 A) + efficiency critical → **PWM** (ATLSxA201D or ATLSxA202D series)
- High current + CW mode + slow system loop (e.g., EDFA pump) → **PWM** is ideal
- Any current + multiple switchers on board → **Synchronizable PWM** (ATLSxA202D series)

7. Performance Analysis: A Professional Noise Taxonomy

A laser diode can emit light and still fail the system requirement. In metrology, spectroscopy, sensing, imaging, pumping, and communication, optical stability can matter as much as power. The professional question is not "is it low noise?" but "which noise mechanism dominates, at what frequency, through which path, and how will the optical system notice it?"

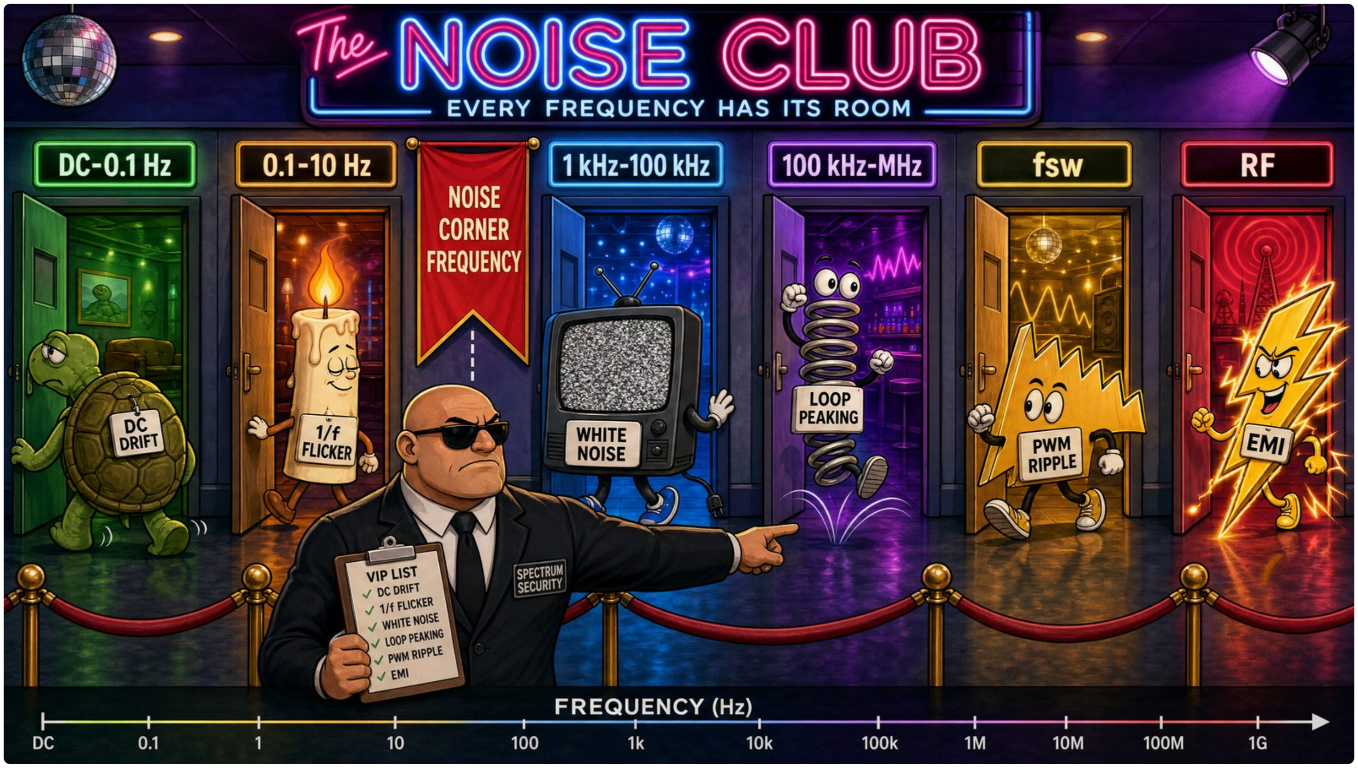

Figure 10. Laser-driver noise sorted by frequency region. The bouncer at "The Noise Club" directs each troublemaker to its frequency room: DC Drift (turtle), 1/f Flicker (candle), White Noise (TV static), Loop Peaking (spring), PWM Ripple (sawtooth), and EMI (lightning bolt). *Design rule:* name the mechanism and its frequency band, then apply the filter or fix that targets that band.

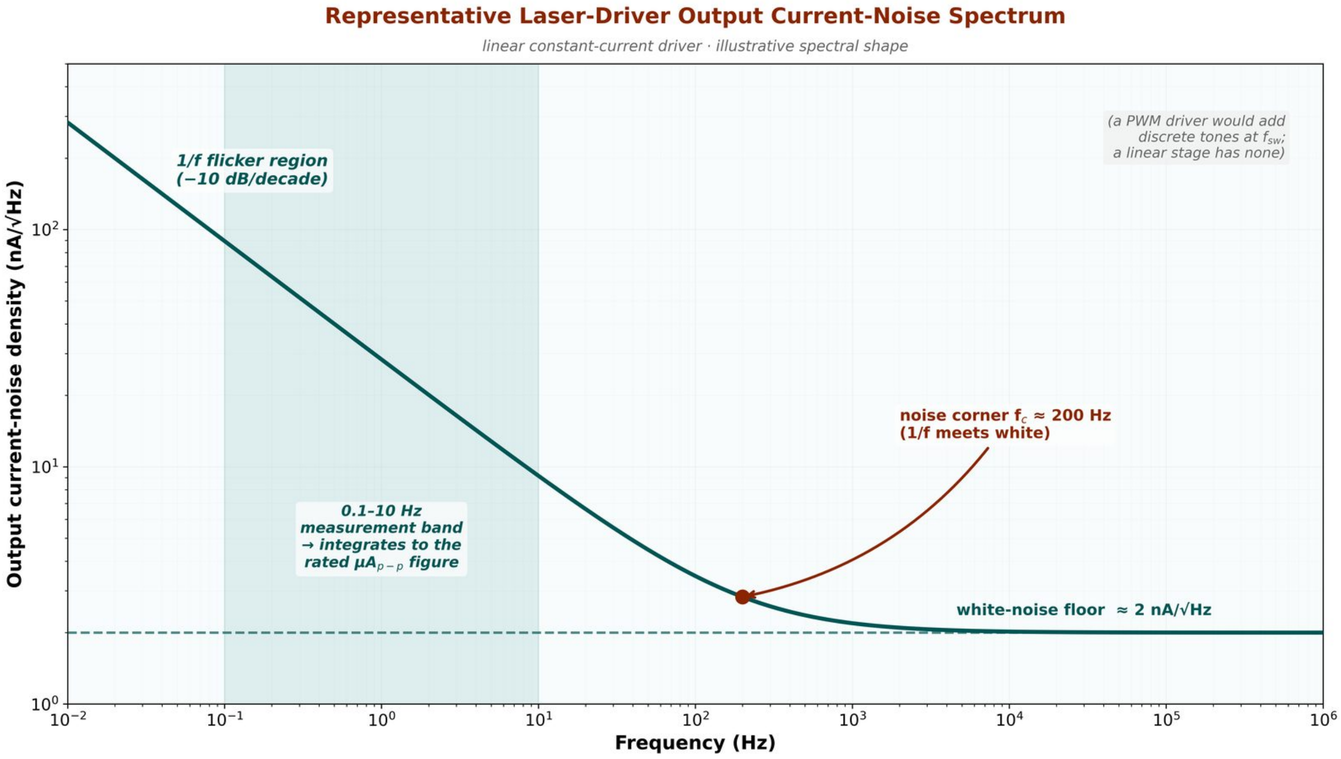

Figure 11. Representative output current-noise spectral density of a linear constant-current driver. The spectrum falls as 1/f (flicker) at low frequency and flattens to a white-noise floor; the **noise corner frequency** is simply where the two meet (here approximately 200 Hz). The shaded 0.1–10 Hz band is the standard low-frequency measurement window whose integral yields the rated µAp-p specification. A linear stage has no switching tones; a PWM driver would add discrete lines at f_sw. *Illustrative spectral shape — see device datasheets for measured values.*

Terminology note (a hard-to-find point): "corner noise" is not a noise type. The low-frequency noise is 1/f (flicker) noise; the noise corner frequency is simply the point where the falling 1/f spectrum meets the flat white-noise floor. Naming the mechanism, not the corner, is what lets you fix it.

Frequency range	Dominant noise	Notes
DC to 0.1 Hz	Long-term drift	Reference, offset, sense-resistor, and PCB thermal drift; sets long-term power and wavelength stability.
0.1 Hz to 10 Hz	1/f flicker; reference, op-amp low-frequency	Important for slow optical-power fluctuation.
10 Hz to 1 kHz	1/f transitioning to white	The transition point is the noise corner frequency.
1 kHz to 100 kHz	Johnson, shot, op-amp and reference white	Main broadband current-noise region.

Frequency range	Dominant noise	Notes
100 kHz to several MHz	Loop peaking, supply, output-filter interaction	Depends on loop bandwidth and compensation.
At f_sw	PWM / switching ripple	Discrete tones at the switching frequency and harmonics — periodic, not white.
MHz to hundreds of MHz	EMI, edge-coupled noise, ringing	Strongly layout-, grounding-, shielding-, and cable-dependent.

Low noise is never solved by one capacitor. The control loop, reference, sense resistor, compensation, layout, grounding, shielding, cable routing, thermal design, and switching behavior all shape the final laser-current noise. ATI's ultra-low-noise ATLSxA103 constant-current laser drivers (ATLS100MA103, ATLS200MA103, ATLS250MA103, ATLS500MA103, and ATLS1A103) are built for ultra-low-noise current drive with output current noise as low as 1.5 µAp-p on the 100 mA variant, scaling to 6 µAp-p on the 1 A variant (0.1–10 Hz bandwidth). The output current is set by an input voltage linearly or modulated by an external large signal up to 1.2 MHz bandwidth (down to 170 ns rise/fall on the 1 A variant; approximately 1 µs on the 100 mA variant). The series features a programmable current limit through a separate port, complete six-sided metal shielding, and a temperature-compensation network that holds output current stable as the controller warms.

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8. ATI Laser-Driver Advantages (Evidence-Based)

ATI laser drivers are positioned through verified features rather than slogans:

- **Full protection** — soft start, soft turn-off, independent hardware current limit (programmable through a separate port on the ATLSxA103 series), over-current, over-temperature, supply under-/over-voltage, and reverse-polarity protection across the families.
- **Ultra-low noise** — output current noise as low as 1.5 µAp-p (0.1–10 Hz, 100 mA variant) on the ATLSxA103 series, scaling to 6 µAp-p on the 1 A variant; 0.05% current-output noise on the ATLSxA201D series.
- **High stability** — typically <100 ppm/°C, with temperature-compensation networks available to hold current as the module warms.
- **High rejection to load variation** — output current remains virtually unchanged even as the laser diode's forward voltage drifts with temperature.
- **High efficiency** — >90% on the ATLSxA201D and ATLSxA202D series, which lowers self-heating and can remove the need for a heat sink in normal operation.
- **Compact size** — small DIP modules (the ATLSxA201D is roughly 20×25.8 mm), with DIP and SMT options on the low-noise series.
- **High reliability** and 100% Pb-free / RoHS-compliant construction.

- **Full shielding / greatly reduced EMI** — a six-sided metal enclosure blocks the vast majority of incoming and outgoing electromagnetic interference, reducing radiated and conducted EMI to negligible levels in typical system configurations.
- **Current monitoring** — real-time, nonintrusive output-current monitor, plus a low-noise 2.5 V reference usable to set current and to feed an ADC/DAC.
- **Optical-power monitoring** — photodiode input for CP mode or for system-level optical-power reporting.
- **Wide modulation bandwidth** — analog input modulates current up to 1.2 MHz bandwidth on the ATLSxA103 series (down to 170 ns rise/fall on the 1 A variant; ~1 µs on the 100 mA variant), enabling high-speed direct modulation of laser diodes.
- **Frequency synchronization** — ATLSxA202D accepts an external sync signal (520–800 kHz) to eliminate beat-frequency interference with other board-level switchers.
- **Never-obsolete policy** — ATI has not discontinued a single product since founding in 1997. Designs using ATI drivers will not face end-of-life surprises.

8.1 Master Specification Comparison

Parameter	ATLSxA103	ATLSxA116	AQCL series	ATLSxA201D	ATLSxA202D	ATLSxA216/217/218
Topology	Linear	Linear	Linear	PWM	PWM (sync)	PWM
Max current	1 A	500 mA	500 mA	6 A	6 A	8–12 A
Input voltage	4.5–5.5 V	6.5–16 V	10–28 V	3–5.5 V	3–5.5 V	5.5–15 V
Current noise	1.5–6 µAp-p (0.1–10 Hz)	300 nAp-p (0.1–10 Hz, ≤500 mA)	Ultra-low (linear, contact ATI for specs)	0.05% (of setpoint)	0.05% (of setpoint)	Contact ATI for specifications
Efficiency	V_load/ V_supply (see note)	V_load/ V_supply (see note)	V_load/ V_supply (see note)	>90%	>90%	>90%
Modulation BW	1.2 MHz	—	—	—	—	—
Sync input	No	No	No	No	Yes (520–800 kHz)	No
Shielding	6-sided metal	6-sided metal	6-sided metal	6-sided metal	6-sided metal	6-sided metal
Package	DIP / SMT	DIP	DIP	DIP	DIP	DIP

All families include soft start, soft turn-off, hardware current limit, OCP, OTP, and reverse-polarity protection.

Note on linear efficiency: A linear regulator's efficiency is approximately V_load / V_supply. For example, a 1.8 V NIR diode on a 5 V supply yields ~36% efficiency, while a 14 V QCL on a 16 V supply yields ~88%. The PWM families (ATLSxA201D/202D/216) maintain >90% efficiency regardless of load voltage.

Note on noise figures. Values are quoted under each family's own standard test conditions and are **not directly comparable across columns**. Always compare at a matched measurement bandwidth and operating current. A peak-to-peak figure over a narrow band (e.g., the ATLSxA103's 1.5–6 µAp-p over 0.1–10 Hz) can read numerically lower than a broadband RMS or percentage figure (e.g., the 0.05% quoted for the 201D/202D) even when the underlying spectral density is higher. State the bandwidth and current beside every number, and convert to a common metric (RMS, or % of setpoint over a defined band) before ranking parts.

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9. Product Selection Guide

Application	Compliance	Recommended ATI Family	Key Spec	Product Page
Ultra-low-noise CW (spectroscopy, metrology, sensing, DPSSL, EDFA)	< 4 V, ≤1 A	ATLSxA103 (100 mA–1 A)	Linear, 1.5–6 µAp-p noise, 1.2 MHz BW, programmable current limit, temp comp	ATLSxA103 series
High-efficiency CW (industrial, pumping, medical)	< 4 V, 1–6 A	ATLSxA201D / ATLSxA202D	PWM, >90% eff, 4 ms soft start, sync input (202D)	ATLSxA201D / ATLSxA202D
High compliance, low current (UV, blue, green, seed lasers)	> 4 V, ≤500 mA	ATLSxA116 (6.5–16 V input)	Linear, 300 nAp-p noise, high compliance	ATLSxA116 series
High compliance, high current (diode bars, DPSSL pumping)	> 4 V, 8–12 A	ATLSxA216 (5.5–15 V input)	PWM, wide input range, high current	ATLSxA216 series
Quantum cascade lasers (gas spectroscopy, chemical sensing)	8–15 V (QCL)	AQCL series (10–28 V input, ≤500 mA)	Linear (must be — noise-sensitive), extra protection, high compliance	AQCL series
General-purpose / legacy replacement	Various	CWD-01-V2	Drop-in, well-documented	Laser drivers (category)
Evaluation and prototyping	—	Evaluation boards	Quick-start testing	Evaluation boards

Note: For the intermediate range (0.5–8 A at compliance > 4 V), contact ATI engineering for application-specific recommendations.

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10. Worked Example: Selecting a Driver for a 500 mW Fiber-Coupled Pump Laser

Given: A 976 nm fiber-coupled pump laser diode rated at 500 mW optical output, I_threshold = 80 mA, I_operating = 450 mA, V_forward = 1.8 V at 450 mA, supply = 5.0 V, noise budget = <0.1% RMS current noise, board has a 600 kHz DC-DC converter.

Step 1 — Mode: CC mode (the fiber coupling is fixed; current stability matters more than optical-power feedback).

Step 2 — Current range: Need 0–450 mA with margin. The ATLS500MA103 covers 0–500 mA.

Step 3 — Compliance: V_forward (1.8 V) + V_sense (~0.2 V) + cable (~0.1 V) = 2.1 V. Supply is 5 V. Headroom = 2.9 V. Adequate for a linear stage.

Step 4 — Noise: The ATLSxA103 series provides ultra-low output current noise (approximately 3–4 µAp-p at 0.1–10 Hz for the 500 mA variant, interpolated from the 2.5 µAp-p at 200 mA and 6 µAp-p at 1 A specifications), well within the <0.1% budget.

Step 5 — Beat frequency: The board's 600 kHz DC-DC sits within the ATLSxA202D sync range (520–800 kHz), but the ATLS500MA103 is linear — no switching frequency to beat. No beat-frequency concern.

Step 6 — Protection: Soft start, hardware current limit, OCP, OTP, reverse-polarity — all included.

Result: Select the **ATLS500MA103** for this application. It meets noise, current, compliance, and protection requirements without additional external components. For rapid prototyping, use the ATLS1A103DEV1.0 evaluation board (low-cost; check current pricing), which comes with a dummy laser on board to emulate an expensive real laser before committing to the final design.

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11. Troubleshooting Guide

Symptom	Likely cause	Fix
Output current lower than commanded	Compliance voltage too low (V_supply − V_forward − V_sense < headroom)	Increase supply or reduce cable resistance
Current oscillation / instability	Loop compensation mismatch or excessive output capacitance	Check compensation network; reduce output capacitance
Slow optical-power drift	Thermal drift in sense resistor or reference	Use temperature-compensated driver (ATLS500MA103)
Periodic ripple on laser current	PWM beat frequency with supply switcher	Synchronize (ATLSxA202D) or separate frequencies
Laser destroyed at power-on	No soft start; inrush spike exceeded diode rating	Use driver with soft start (all ATI families include it)

Symptom	Likely cause	Fix
EMI failing system-level test	Large output loop area; unshielded driver	Shorten LDA-LDC loop; use ATI shielded module
Current monitor reads zero	Open laser connection or protection tripped	Check connections; verify no fault flags
Optical power fluctuates in CP mode	Back-reflections or stray light corrupting photodiode	Switch to CC mode or shield the photodiode from stray light

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12. Frequently Asked Questions

Q1: What is the difference between a laser driver and a laser power supply? A laser driver is a precision current source (or optical-power loop) designed specifically for laser diodes, with soft start, protection, monitoring, and noise control. A power supply provides voltage and leaves current regulation to the user. Driving a laser diode directly from a power supply risks destruction from inrush, noise, and lack of protection.

Q2: Can I use a general-purpose constant-current source to drive a laser diode? Technically yes, but you lose soft start, soft turn-off, over-temperature protection, current monitoring, EMI shielding, and noise optimization. A dedicated laser driver integrates all of these in a compact, tested module.

Q3: Why can't I just use a constant voltage to drive a laser diode? A laser diode's forward voltage changes with temperature (~−2 mV/°C). Under constant voltage, the current changes as Vf drifts — causing optical power to fluctuate. A constant-current driver forces the same current regardless of Vf drift, keeping optical power stable at constant temperature.

Q4: What is compliance voltage and how do I calculate it? Compliance voltage is the maximum voltage the driver can develop across the load. Calculate: V_compliance ≥ V_forward(max) + I_LD × R_sense + V_cable. If the total exceeds compliance, the driver saturates. Always use worst-case V_forward at the lowest operating temperature. See the Selection Guide table (§11) for family recommendations by compliance range.

Q5: How do I choose between CC and CP mode? Use CC when you need predictable, limited electrical stress and the optical coupling is stable. Use CP when the system cares about delivered optical power and can tolerate current rising to maintain it. Always keep a current limit active in CP mode — back-reflections can fool the photodiode sensor.

Q6: What causes laser-driver noise and how do I reduce it? Noise comes from the reference, sense resistor, error amplifier, loop compensation, layout, grounding, shielding, and switching. Reduce it by choosing a low-noise driver (ATLSxA103 series), minimizing loop area, using stable references, and filtering the control input.

Q7: Why does ATI use six-sided metal shielding on laser drivers? A complete six-sided metal enclosure blocks both incoming EMI (which could modulate laser current) and outgoing EMI (which could disturb adjacent sensitive circuits like photodetectors or lock-in amplifiers). Partial shielding (top-only lids) leaves gaps for ground-plane coupling and edge radiation. Full enclosure is especially critical in instruments with sensitive detectors near the laser driver.

Q8: What is frequency synchronization and when do I need it? If your board has multiple switching converters, their PWM frequencies can beat against each other, creating low-frequency interference that passes through filters. ATI's ATLSxA202D accepts an external sync signal to lock its switching frequency to your system clock, eliminating beat interference.

Q9: What is a hardware current limit and why is it important? A hardware current limit is an independent safety mechanism that prevents the laser current from exceeding a user-set maximum, regardless of what the control loop is doing. If the control loop malfunctions, software glitches, or the photodiode fails in CP mode, only an independent hardware limit can save the laser diode from destruction.

Q10: How long do ATI laser drivers last? Will they be discontinued? ATI has not discontinued a single product since founding in 1997. Designs using ATI drivers will not face end-of-life surprises, forced redesigns, or last-time-buy scrambles.

Q11: How do I choose between a linear and a PWM laser driver? Use linear for currents ≤500 mA to 1 A when noise is the priority. Use PWM for currents >1 A or when efficiency is critical. PWM is not always noisy — in slow-loop CW systems (e.g., EDFA pump lasers), the high-frequency ripple is invisible to the system.

Q12: What is the sense resistor’s role in noise performance? The sense resistor converts output current to a feedback voltage. Its Johnson noise ($V_n = \sqrt{(4kTR\Delta f)}$) referred to current gives $I_n = \sqrt{(4kT\Delta f / R_{SENSE})}$. A larger R_{SENSE} actually lowers the current-noise contribution and improves resolution, but costs compliance headroom and increases dissipation. Use a low-TCR metal-film or wirewound resistor and balance noise against headroom.

Q13: Can I modulate the laser current with an external signal? Yes. ATI’s ATLSxA103 series accepts an analog modulation input that directly modulates the output current up to 1.2 MHz bandwidth (down to 170 ns rise/fall on the 1 A variant; approximately 1 μs on the 100 mA variant). This enables direct current modulation for applications such as spectroscopy, communications, and sensing.

13. Reliability and Long-Term Stability

Laser diode lifetime depends critically on the driver’s ability to maintain stable, stress-free operating conditions over years of continuous operation.

Degradation mechanisms the driver must manage:

- **Thermal cycling stress** — Repeated power-on/off cycles create thermal expansion mismatches in the diode package. Soft start and soft turn-off reduce thermal shock at each cycle, extending facet and bond-wire life.

- **Current overshoot aging** — Even brief current spikes above the rated maximum accelerate catastrophic optical damage (COD) at the laser facet. The hardware current limit prevents this regardless of control-loop state.
- **Slow parametric drift** — As a laser diode ages, its threshold current increases and slope efficiency decreases. In CC mode, this means optical power slowly drops (predictable, monitorable). In CP mode, the loop compensates by increasing current — which can accelerate aging if no current limit is set.
- **Sense-resistor drift** — The sense resistor's TCR directly affects current accuracy over temperature. ATI's temperature-compensation network on the ATLSxA103 series counteracts this drift.

Derating guidelines:

- Operate the laser at ≤80% of its absolute maximum rated current.
- Set the hardware current limit (LILM) to no more than 90% of the diode's absolute maximum.
- Ensure the driver's ambient temperature stays within its rated range (check the specific model's datasheet for exact limits).
- Recalibrate optical power annually in precision applications; use the current monitor output for drift tracking.

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14. Best Practices and Common Mistakes

Best practices:

1. **Always set the hardware current limit before connecting the laser.** Wire the LILM port first, verify the limit with a dummy load, then connect the real diode.
2. **Minimize the output loop area.** Keep the wires from LDA (anode) and LDC (cathode) short, twisted, and close together. Large loops radiate and receive EMI.
3. **Use a stable, low-noise power supply.** The driver's power-supply rejection ratio (PSRR) is finite; supply noise that exceeds the PSRR will appear on the output.
4. **Decouple the supply at the driver pins** with a low-ESR ceramic capacitor (1–10 µF) plus a bulk electrolytic (47–100 µF).
5. **Never hot-plug a laser diode into a powered driver.** Always power down, connect, then power up.
6. **Ground the laser diode case** to the driver's ground plane to prevent floating-case EMI pickup.
7. **Use shielded cables** for any connection longer than 5 cm between the driver and the laser.

Common mistakes:

1. **Forgetting to set the current limit** — leaving LILM unconnected or at maximum defeats the protection.
2. **Excessive output capacitance** — adding large capacitors on the output "for filtering" can destabilize the control loop and cause oscillation.

3. **Running in CP mode without understanding stray-light effects** — back-reflections fool the photodiode and cause the driver to over-drive the laser.
4. **Using a switching supply directly adjacent to the driver** without frequency separation or synchronization — creates beat-frequency interference.
5. **Ignoring compliance margin** — operating with <0.5 V headroom causes the driver to drop out of regulation intermittently.

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15. Summary and Conclusion

A laser driver is a precision current source engineered to keep a laser diode operating safely, stably, and quietly over its entire lifetime. Unlike a general-purpose power supply or constant-voltage source, a dedicated laser driver provides:

- **Constant-current control** that is immune to the laser diode's forward-voltage drift with temperature.
- **Soft start and soft turn-off** that eliminate the inrush spikes which cause catastrophic optical damage.
- **An independent hardware current limit** that protects the diode regardless of control-loop state or user error.
- **Low noise** that preserves the laser's spectral purity and intensity stability.
- **EMI shielding and compact layout** that prevent interference in sensitive optical systems.

The choice between CC and CP mode, between linear and PWM topology, and between protection features depends on the application — but the fundamental requirement is always the same: the driver must deliver exactly the commanded current, with no surprises, for years of continuous operation.

ATI's ATLSxA103 series represents the state of the art in low-noise, fully protected linear laser drivers for currents up to 1 A. For high-compliance applications (>4 V), the ATLSxA116 series extends the same ultra-low-noise philosophy to 6.5–16 V input with 300 nAp-p output noise. For higher-current applications, the ATLSxA201D and ATLSxA202D series deliver >90% efficiency with the same comprehensive protection philosophy.

For technical support, evaluation boards, and application guidance, contact ATI engineering at www.analogtechnologies.com/contact.html.

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16. Related ATI Products

Category	Product	URL
TEC Controllers	Full family (for laser temperature stabilization)	TEC Controllers
TEC + Laser Combos	Integrated TEC controller + laser driver	Combo Controllers
Precision Thermistors	For TEC feedback loops	Thermistors

Category	Product	URL
TEC Modules	Peltier coolers for laser packages	TEC Modules
High Voltage Power Supplies	For gas lasers, detectors	HV Power Supplies
ATLSxA103 Evaluation Board	For rapid prototyping of ATLSxA103 series	ATLS1A103DEV1.0
Evaluation Boards	For rapid prototyping of laser drivers	Laser Driver Eval Boards

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4. ATLS500MA103 datasheet: https://www.analogtechnologies.com/document/ATLS500MA103.pdf
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