An Analog Current Controller Design for Laser Diodes

Todd P. Meyrath[1]

Atom Optics Laboratory
Center for Nonlinear Dynamics
University of Texas at Austin

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This note gives a simple and inexpensive design for a stable analog current controller for laser diodes. The present design can supply up to 500 mA with a set current limit for the desired range. Measuring current noise with the current output monitor through a bandpass amplifier, under test condition Iout=200 mA, we observe rms noise of about $100\,\mu\mathrm{V_{rms}}$ (on a 2 V dc signal) in the 2 Hz to 200 kHz (3dB) band. This corresponds to $5 : 10^5$ rms current noise. In the 2 Hz to 20 kHz band, the rms noise was about $20\,\mu\mathrm{V_{rms}}$, which is about $1 : 10^5$ rms current noise. The drift is limited by the sense resistor which is between -50ppm/C and 100ppm/C according to the manufacturer. Self-heating of the sense resistor is rather small and most changes would likely be due to ambient temperature variations. More practically, we have observed drift under $1 : 10^4$ on the few hour scale from tens of seconds after turn on. We have not yet measured a longer term drift, but expected to be order $1 : 10^5$ (long term stability of the voltage reference).

Our laser diodes are the MLD780-100S5P from Intelite Inc. with 90 mW output at 780 nm and operating current of around 120 mA and GH0781JA2C from Sharp with 120 mW at 784 nm. The first is about $200 and used in a grating stabilized saturation locked setup. These were used rather than the later because it was much easier to get them single mode and on Rb resonance at 780 nm. The later diodes are injection locked slaved to the grating stabilized master lasers. They were a mere $25 obtained from Digikey electronics (425-1809-ND). All the laser diodes have temperature controllers (WTC3243 from Wavelength Electronics) driving TECs to stabilize the temperature. In addition to the current controller, the laser diode has the protection-filter circuit right on the diode (in the laser housing at the end of the twisted pairs to the diode) shown in the Figure 1.

The current controller design is based on a standard PID feedback loop and a buffered current output. The current sense is done with a Caddock SR10 $1\,\Omega$ 4-point sense resistor and measured by an INA128 instrumentation amplifier. The amplifier is set to have a gain close to 10 and may be trimmed for accuracy giving a current monitor of 1 V for every 100 mA of output current. This trimming, of course, is for

[1]Please send comments, questions, corrections, insults to *meyrath@physics.utexas.edu*

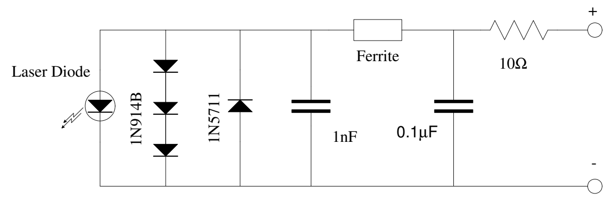

Figure 1: Protection and filter circuit, this circuit is located in the laser diode housing. The protection circuit help defend the laser diode from electrocution and the filter is to guard against any high frequency pickup from the power transport lines (twisted pairs) which could cause undesired modulation (side bands which potentially can royally screw up an atomic physics experiment). We also have a switch in front of this circuit in the housing which may be used to short out the diode circuit after switching it off before removing power connectors.

the purpose of removing the small absolute error of the sense resistor if such accuracy is desired. In principle, however, it is only really important to have noise-free operation and stability rather than accuracy. We trimmed the output accuracy to under 0.1%. Connections for the PID are single opamp configuration, where the various time constants are coupled. This is hardly a problem in this circuit. In general, one can think of C0 as the high frequency roll-off, C1 and R0 as the integrator, R1/R0 as the proportional gain level, and R2 and C2 with R1 as the differential. We found excellent performance without the differential part of the circuit, simply omitting these components (R2 and C2). Although pads for adjustable resistors are given, we found it unnecessary to adjust and simply used fixed resistors of values R0=R1=4.99 kΩ, and capacitors C0 of 39 pF and C1 of 10 nF. This gives an integration bandwidth of about 20 kHz and a unity proportional level.

The current set point that may be sent to the diode via front panel control is limited by the resistor labelled Rlimit. Various limiting values between 100 mA and 500 mA are given on the table in the schematic. The accuracy of the current limit is limited by the absolute accuracy of the voltage reference, which is about ±2%. The fine adjust potentiometer gives a resolution of adjustment (for few degree turns) of a few microamps on the output current (try that with a digital circuit!)

The purpose of the relay is for protection. In the event of power failure, when the power returns, the current is disabled until the enable button is pressed. There is also a disable switch and an LED to indicate active status. The output is disabled by pulling the opamp input voltage to ground. This is done through a small RC filter with time constant 0.1 s which gives a relatively slow switch on and off.

The photodiode amplifier is for power monitoring. This is hooked up to the photodiode that is typically included in a laser diode module. The simple amplifier has a transimpedance gain between 4 kΩ and 6 kΩ which was appropriate for our laser diode. The adjustment allows some sort of output voltage calibration if desired.

Comment on performance, we had previously used WLD3343 modules from Wavelength electronics for injection slaved lasers and NIST current controllers[2] for our grating stabilized master lasers. The rather pricey modules from wavelength electronics were outperformed and the NIST module matched by the given circuit in terms of noise stability (of the laser output measured on a Fabry-Perrot Etalon) — that is, this circuit has a lot of bang for your buck.

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[2]As far as I know this device has no model number or available specifications. Although they perform well as current sources, they have the annoying property of switching themselves down arbitrarily on the day time scale. This was the original reason that Jay suggested that we apply the design presented here to our lasers, which is a version of the same concept circuit which operates our magnetic trap.

Parts: The boards used are presensitized PCBs to be exposed with a fluorescent lamp, they were obtained from *www.circuitspecialists.com*. The layouts given were printed on overhead projector transparencies and the boards exposed with a simple fluorescent desk lamp for about 10 minutes. Most of the other parts were obtained from *www.mouser.com*, *www.digikey.com*, or *www.alliedelec.com*.

Parts			
Quantity	Part	Manufacturer	Description
2	2N7000	On Semiconductor	N-channel MOSFET, TO-92
2	AD820	Analog Devices	Single-supply precision opamp, DIP
1	INA128	Texas Instruments	adj. gain intrumentation amplifier, DIP
2	BUF634	Texas Instruments	high speed 1/4 amp buffer, DIP
1	W171DIP-27	Magnecraft	12V normally open DPST relay, DIP
2	31-5538-10RFX	Amphenol RF	RA PCB mount BNC receptacle
1	3590S-2	Bourns	$20\,\mathrm{k}\Omega$ PCB Potentiometer Model 3590
1	3590S-2	Bourns	$2\,\mathrm{k}\Omega$ PCB Potentiometer Model 3590
1	LM399	National Semiconductor	6.95V stable voltage ref
2	GP11MCKE	ITT Ind.	SPST momentary push button switch
1	SR10 $1\,\Omega$	Caddock Electronics	4-point sense resistor
1	64W 101	Spectrol	$100\,\Omega$ Trimpot
1	64X 202	Spectrol	$2\,\mathrm{k}\Omega$ Trimpot
2			Ferrite Core
3	1N914B	Fairchild Semiconductor	high speed diode
1	1N5711	Vishay	Schottky Diode
2			$470\,\mu$F electrolytic capacitor
			$10\,\mu$F Solid tantalum capacitor
			PCB LED
			1% metal film resistors
1	GD101	Ever-Muse, *www.circuitspecialists.com*	100x150mm double-sided PCB

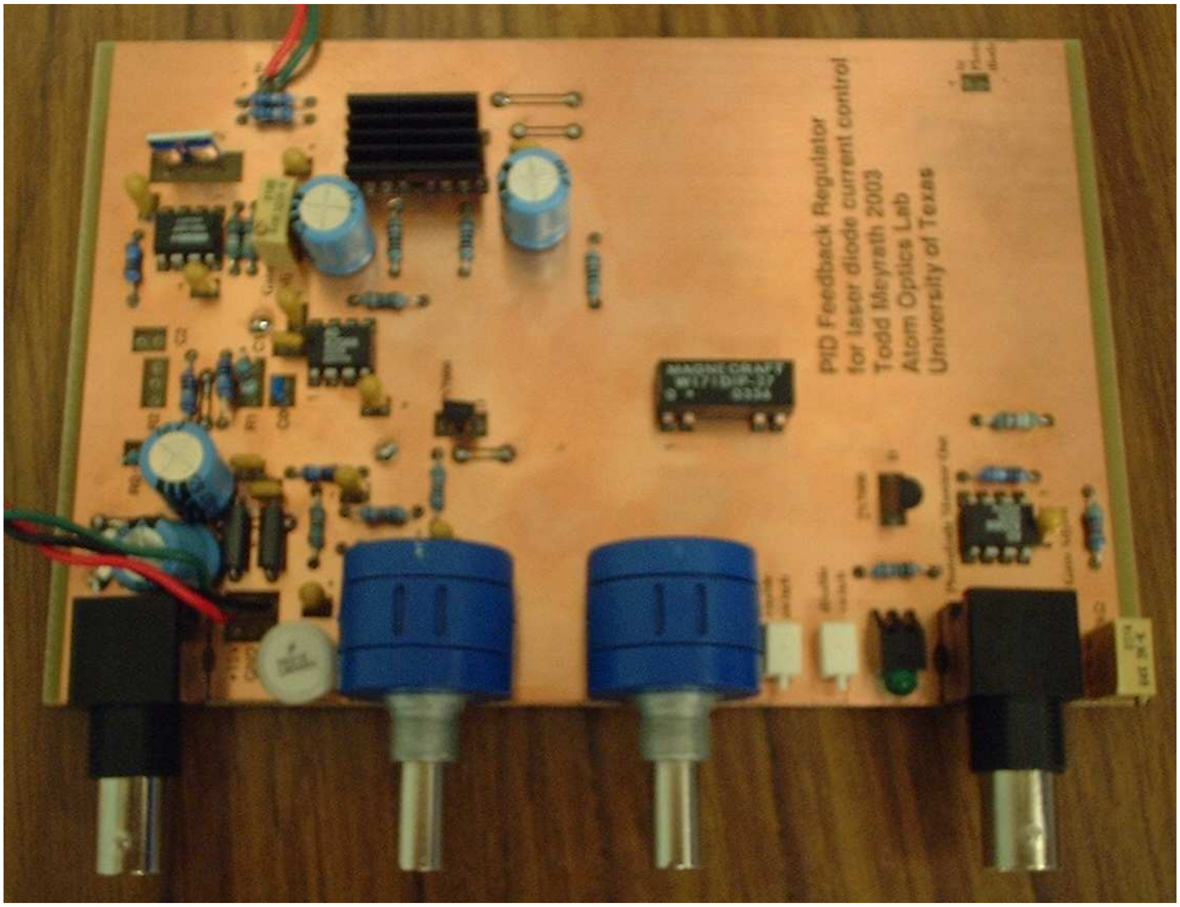

Figure 2: An assembled circuit. The current regulation circuit is on the left. The output stage buffers are under the heat sink, left top. The small heat sink is attached with 5 minute epoxy onto both buffer ICs. The protection relay is in the middle and photo diode amplifier is to the right. Front panel is (left to right): BNC - laser diode current monitor, potentiometer - course current adjust, potentiometer - fine current adjust, enable button, disable button, status LED, BNC - photodiode monitor, trimpot - photodiode amplifier gain adjust. We used the tiny buttons in order to prevent the mistake of accidently changing the state of the driver. In the rare occasion that the current needs to be disabled (or re-enabled), the buttons may be pressed with a screw driver through a hole in the front panel. Naturally, one may elect to attach larger switches.

PID FEEDBACK REGULATOR CIRCUIT FOR LASER DIODE CURRENT CONTROL

Todd Meyrath
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Current Output: 0 to 0.5Amps
current limit range to be set

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Output Limit Resistor:
max current for Rfine-> 0, Rcourse->20k
Imax = (0.695 A) Rcourse/(Rlimit+Rcourse)
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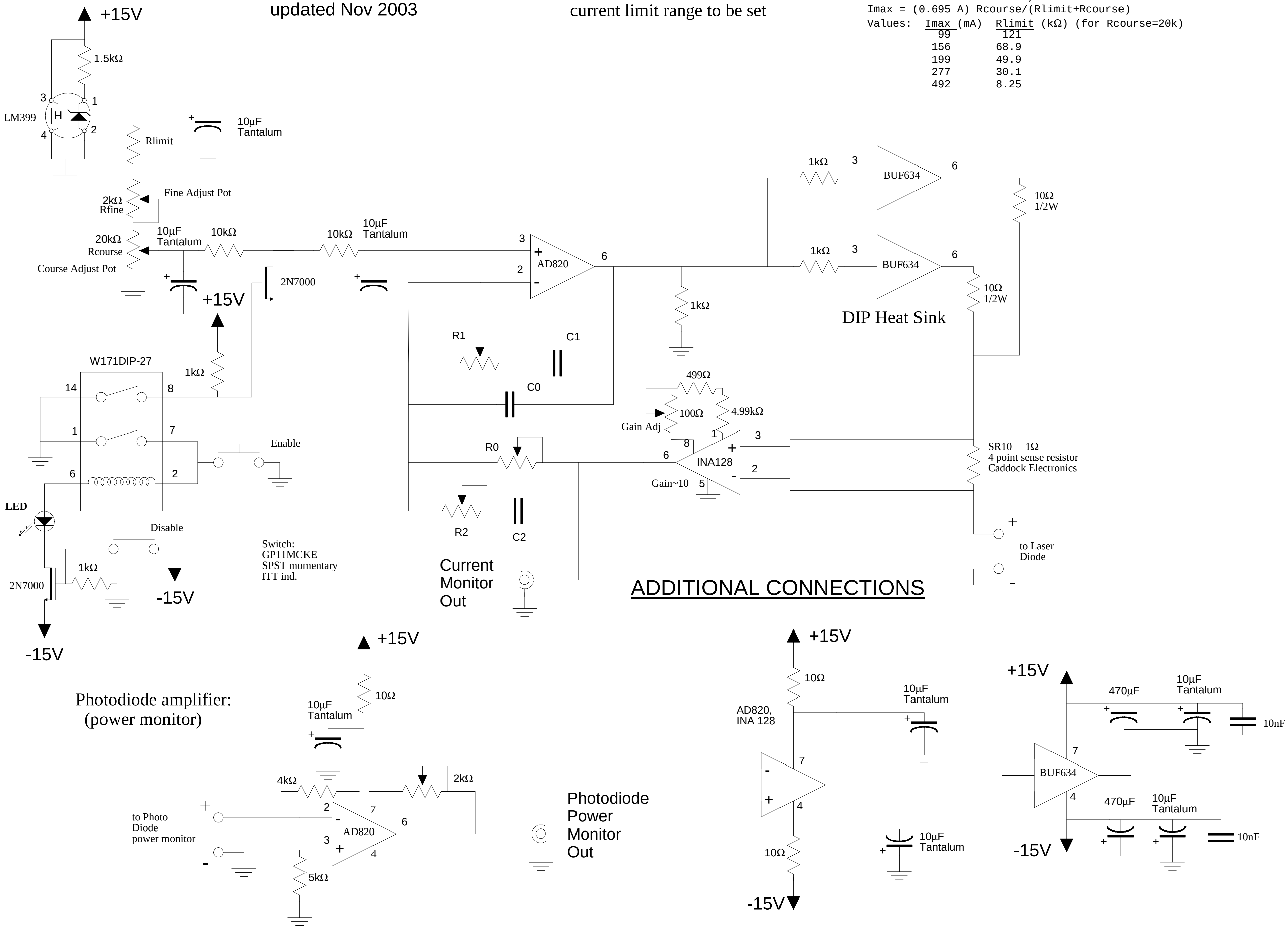
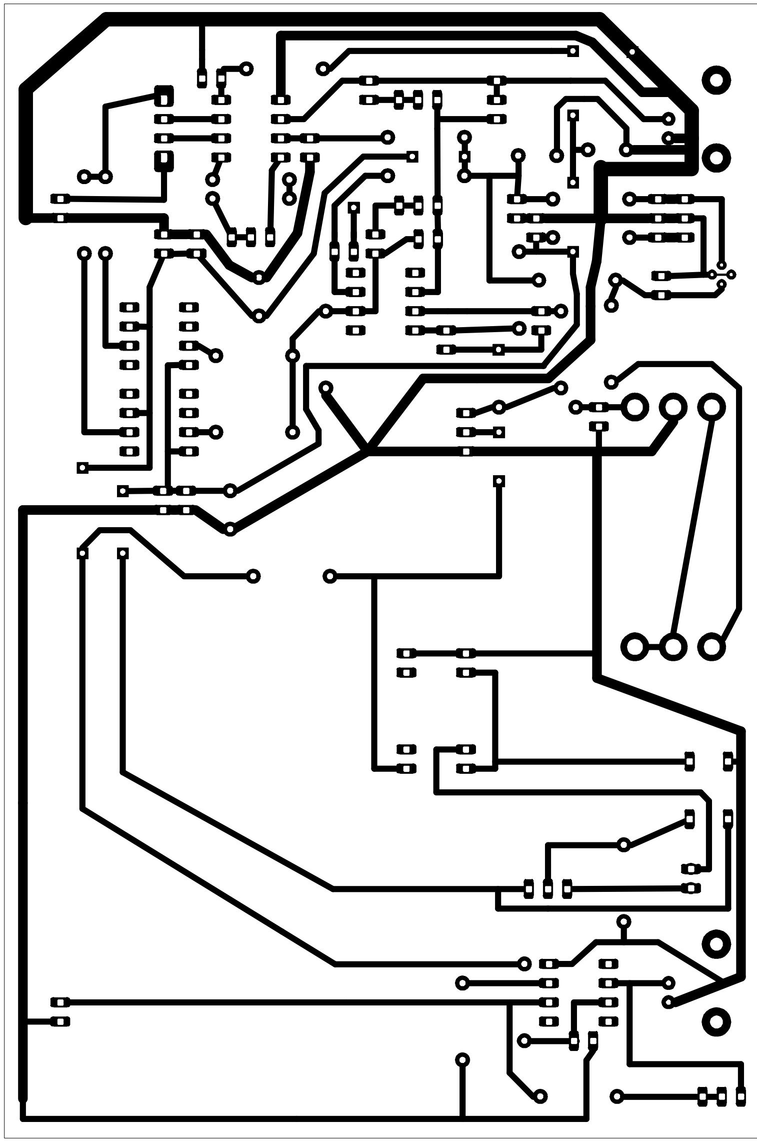
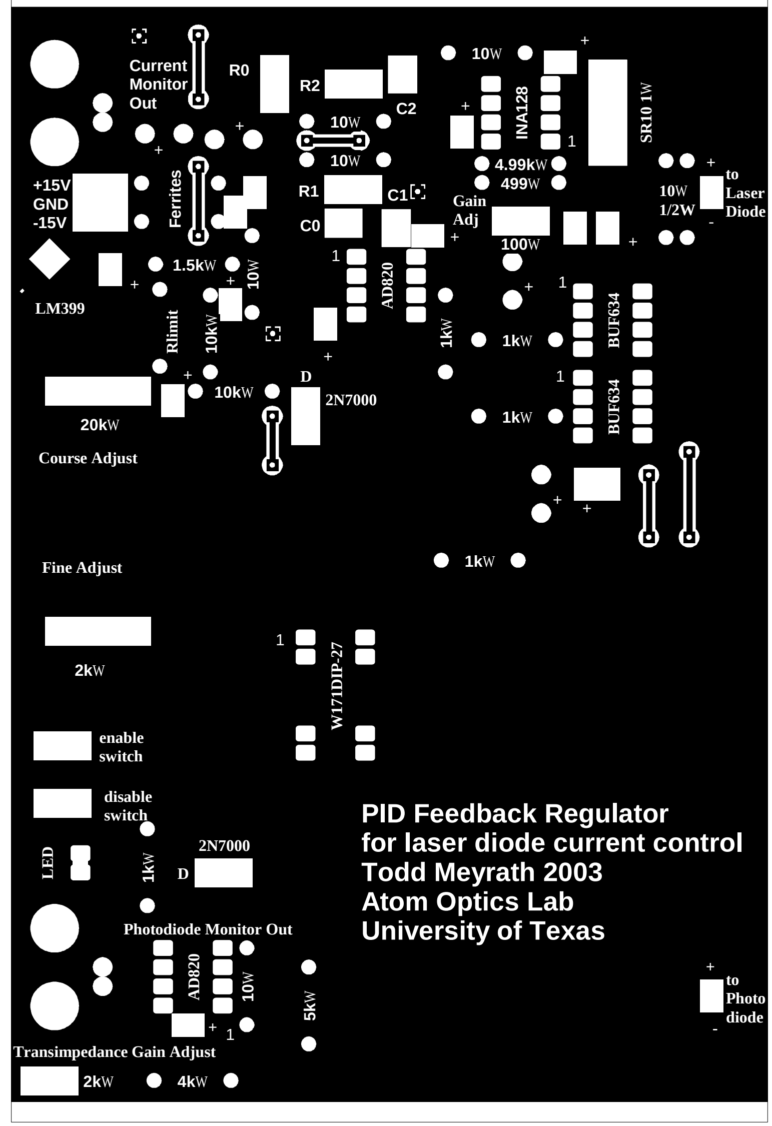
Values:

Imax (mA)	Rlimit (kΩ) (for Rcourse=20k)
99	121
156	68.9
199	49.9
277	30.1
492	8.25






Current
Monitor
Out
R0
R2
C2
10W
10W
10W
INA128
SR10 1W
4.99kW
499W
1
+15V
GND
-15V
Ferrites
R1
C1
C0
Gain
Adj
100W
10W
1/2W
to
Laser
Diode
LM399
1.5kW
10W
1
AD820
Rlimit
10kW
10kW
D
2N7000
1kW
1kW
BUF634
1kW
BUF634
20kW
Course Adjust
Fine Adjust
1kW
2kW
1
W171DIP-27
enable
switch
disable
switch
LED
1kW
2N7000
D
PID Feedback Regulator
for laser diode current control
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Atom Optics Lab
University of Texas
Photodiode Monitor Out
AD820
10W
1
5kW
to
Photo
diode
Transimpedance Gain Adjust
2kW
4kW