Multipurpose Analog PID Controller

Todd P. Meyrath[1]

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

March 14, 2005
revised December 10, 2005

See disclaimer[2]

This analog circuit is intended to be used as a multipurpose PID controller. The schematic and PCB given here may be setup to be used as a logarithmic laser intensity controller, laser diode current controller up to 1/2 Amp directly, temperature controller, controller for high current device, etc... These configurations depend on which options are used, and in some cases, what external devices to which it is interfaced. The layout was intended to be flexible so that it can accommodate many different possibilities. I hate redesigning the same circuit for various applications. Most likely I have forgotten many possibilities, but using the simple voltage sense and voltage control output, the circuit should be useful for many applications assuming appropriate external components are used.

There are several options for setpoint input, sense return, and output drive. The PID may be operated using a single opamp, or a multiple opamp setup. These are standard configurations, the former has the advantage of fewer components but has coupled PID characteristics. The latter has independent PID characteristics so they may be optimized independently. The setpoint circuit includes options for an analog input, a potentiometer or trimpot offset adjust, a gain or inversion option. The sense possibilities include a voltage/current sense, high current sense, direct output current sense, or a logarithmic photodiode sense. The output stage may be set up to drive up to 1/2 Amp of current either as a control single or directly driven current controller. The circuit requires a dual $\pm 15\,\mathrm{V}$ supply.

As mentioned, the circuit my be set to use single or multiple opamp PID, use the single *or* the multiple opamp PID hook-up as in the table:

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

[2]Disclaimer: The author provides this and other designs on the web as a courtesy. There is no guarantee on this or any other designs presented, use at your own risk. The author also comments that the suggested parts used are not an endorsement of any manufacturer or distributer.

Single OpAmp PID hook-up	
Use	C1 to C3, R1 to R4, U1, U2
Omit	C4 to C6, R5 to R9, R11, R12, U3 to U5
Short[a]	R10, R13
Proportional Gain	$(R1 + R2)/R3$
Integration time	$R3 \times C2$
Differentiation time	$(R1 + R2) \times C3$
Notes: R4 limits differential gain, C1 gives high frequency roll-off.	

Multiple OpAmp PID hook-up	
Use	R1 to R3, R5 to R9, (R10 to R13 = 1 kΩ)
	C2, C4 to C6, U1 to U5
Omit	C1, C3, R4
Short[a]	C2
Proportional Gain	$(R1 + R2)/R3$
Integration time	$(R5 + R6) \times C4$
Differentiation time	$(R7 + R8) \times C5$
Notes: R9 limits differential gain, C6 gives high frequency roll-off.	
[a]use a 0 Ω resistor, 1206 package.	

The summer used for the multiple opamp PID is an inverting summer, in some cases, it is desired to re-invert the signal. Use as in the table:

Output inverter option used	
Use	R14, R15 = 1 kΩ, U6
Output inverter option not used	
Omit	U6
Short[a]	R14, R15
[a]use a 0 Ω resistor, 1206 package.	

The circuit is naturally bi-polar, however, some cases require a un-polar output. Use the simple diode rectifier as in the table:

Output rectifier option used	
For positive output only, use	R17 = 10 kΩ, D1
For negative output only, use	R17 = 10 kΩ, D1 (reverse diode direction drawn on schematic and layout) omit R61 in either case.
Output rectifier option not used	
Omit	R17
Short[a]	R61
[a]use a 0 Ω resistor, 1206 package.	

By convention, we will not list decoupling capacitors to be omitted when the associated IC is listed. The associations are given on the table:

Supply decoupling caps associated with ICs		
IC	Capacitors	Value
U1	C10,C11	0.1 μF
U2	C12,C13	0.1 μF
U3	C14,C15	0.1 μF
U4	C16,C17	0.1 μF
U5	C18,C19	0.1 μF
U6	C20,C21	0.1 μF
U7	C8	0.1 μF
U8	C22,C23	0.1 μF
U9	C24,C25	0.1 μF
U10/U11	C26,C27	0.1 μF
U10/U11	C28,C29	10 μF

There are a number of setups for the setpoint, most are summarized in the table here, but the user can have some imagination and come up with others:

Setpoint Options	
Option	Instructions
Analog input only	Use: J1, D2, R22 Short: R18, R57 Omit: R19 to R21, R23 to R35, R58, R59 D3, D4, C9, C34, C35, U9
Potentiometer input (zero adjust) only	Use: R28 or R35 (trimpot *or* potentiometer), R26, R27, R29, R30, C9, C34, C35, D3, D4 Short: R21, R57, (R31 and R34) *or*[a] (R32 and R33) Omit: J1, D2, R18 to R20, R22 to R25, U9
Analog input with zero adjust	Use: J1, D2, R22, R28 or R35 (trimpot *or* potentiometer), R26, R27, R29, R30, C9, C34, C35, D3, D4, U9 Short: (R18 and R20) *or*[b] (R19 and R21) and (R31 and R34) *or*[a] (R32 and R33)
add in gain adjust	when using U9, use R23 to R25, the gain is $1 + \frac{50\,\mathrm{k}\Omega}{\mathrm{R23+R24+R25}}$
[b]Invert setpoint signal	Short: (R18 and R20) *or* (R19 and R21) omit other 2, remember that pin 3 of U9 is non-inverting and pin 2 is inverting.
Unipolar zero adjust	(short R58, omit R26, D3, C34) *or* (short R59, omit R30, D4, C35) use R27 or R29 as $0\,\Omega$ as appropriate.
[a]Potentiometer direction	Short: (R31 and R34) *or* (R32 and R33) omit other 2, the direction of increase depends on if it is hooked to the inverting or non-inverting pin of U9.

The several sense options are summarized in the table. The photodiode uses a logarithmic amplifier so that it may operate over many orders of magnitude. The other options are all really the same thing depending on interpretation. The current/voltage sense uses either a 'sense' or load resistor from a current or voltage source. R46 is included for the option of breaking the ground connection or adding additional load to the driving sensor. This option would be used for instance in a high current controller where a hall sensor is used. Another version is a high current sense using R47, the PCB is setup for an SR20 2 Watt 4-point sense resistor (Caddock Electronics). Depending on the resistance used, this resistor can directly measure up to 15 Amps. An additional current sense that can be used is a direct output measurement. In this case, there is no control output signal, and the buf ICs directly supply up to 1/2 Amp to a load. In this low current driver mode, no external components are needed. For the higher current cases, a high power output stage is needed, and is controlled with the control output signal.

Sense options	
Photodiode	Use: R36 to R39, (R56 *or* R60), C0, C7, C8, U7 Short: R40 Omit: J3, R41, R42 to R47, R54, U8
Current/voltage sense	Use: J3, R42 to R46, U8 Short: R41 Omit: R40, R36 to R39, R47, R56, R60, C0, C7, C8, U7
High current sense	Use: R42 to R44, R47, U8 Short: R41 Omit: J3, R40, R36 to R39, R45, R46, R56, R60, C0, C7, C8, U7 connect up to 15 A (depending on R47 value) through J5 to J6
Direct output current sense	Same as high current sense, but short R54, omit R55, for use with the buffer output stage. connect load across J6 to J7.

For the BNC connectors, the board is setup to accept either the right angle receptacle (227222-1) or the vertical receptacle (227161-1). The vertical receptacle my be mounted on the top or the bottom of the board.

The author would like to thank Gabriel Price for testing out the multiple opamp PID and his ideas with this, and also the suggestions and comments of Florian Schreck and Hrishikesh Kelkar. For pointing out typos thanks to Jonathan Hayes.

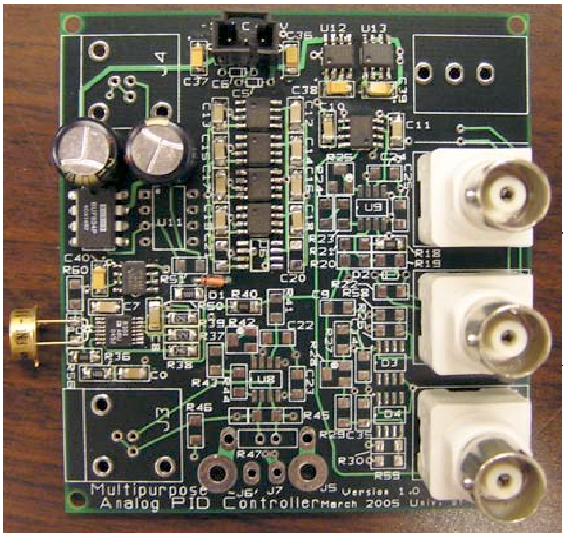
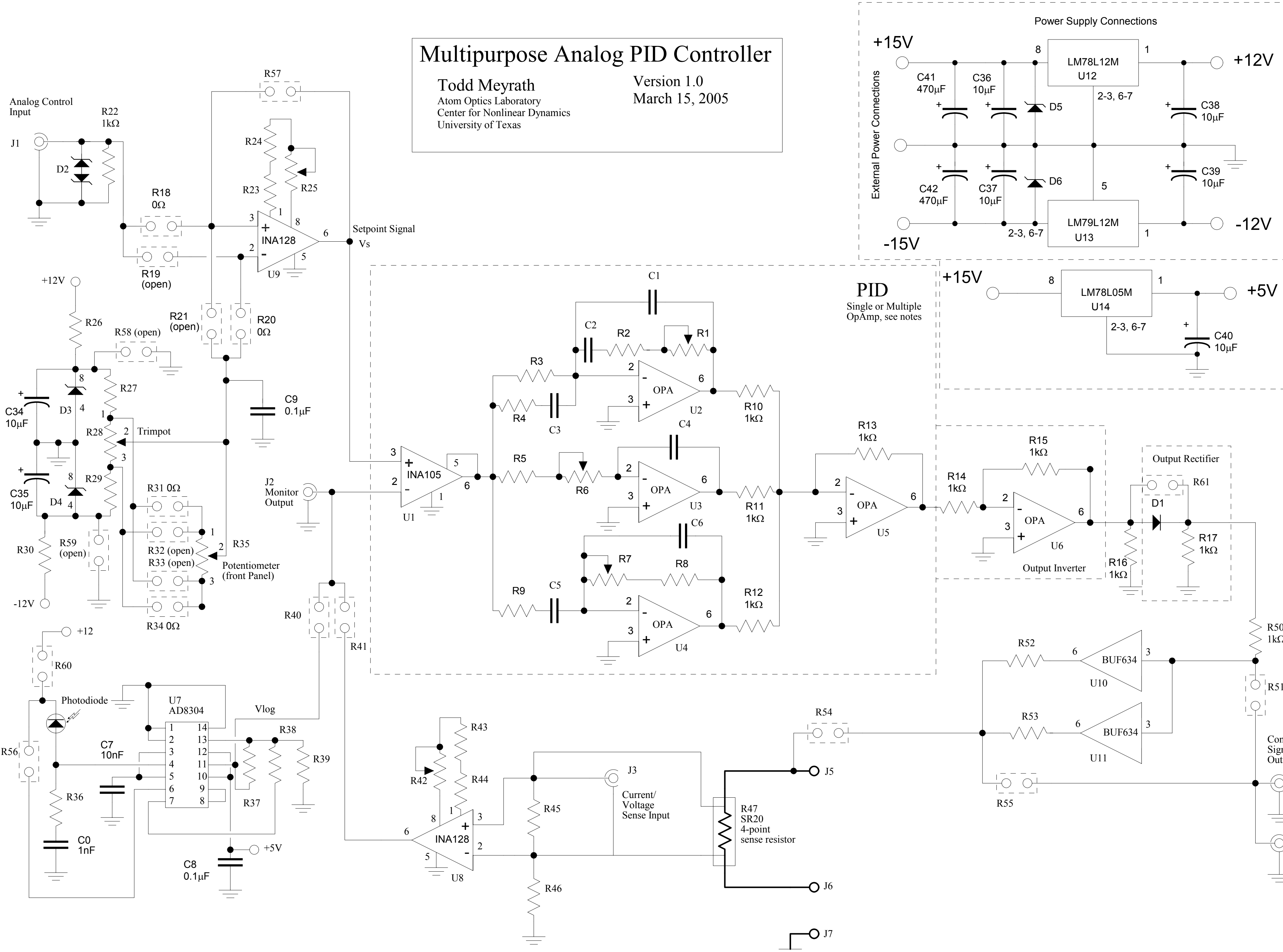


Figure 1: A board set up for a laser intensity control circuit.



Multipurpose Analog PID Controller
Todd Meyrath
Atom Optics Laboratory
Center for Nonlinear Dynamics
University of Texas
Version 1.0
March 15, 2005
Power Supply Connections
External Power Connections
+15V
-15V
+12V
-12V
+5V
LM78L12M U12
LM79L12M U13
LM78L05M U14
C41 470µF
C42 470µF
C36 10µF
C37 10µF
C38 10µF
C39 10µF
C40 10µF
D5
D6
2-3, 6-7
Analog Control Input
J1
D2
R22 1kΩ
R18 0Ω
R19 (open)
R57
R24
R23
R25
INA128 U9
Setpoint Signal Vs
R21 (open)
R20 0Ω
C9 0.1µF
+12V
R26
R58 (open)
R27
R28
Trimpot
R29
C34 10µF
C35 10µF
D3
D4
R30
-12V
R59 (open)
R31 0Ω
R32 (open)
R33 (open)
R34 0Ω
R35
Potentiometer (front Panel)
J2 Monitor Output
INA105 U1
R40
R41
PID
Single or Multiple OpAmp, see notes
C1
C2
R2
R1
R3
R4
C3
OPA U2
R10 1kΩ
C4
R5
R6
OPA U3
R11 1kΩ
C6
R7
R8
R9
C5
OPA U4
R12 1kΩ
R13 1kΩ
OPA U5
R14 1kΩ
R15 1kΩ
OPA U6
Output Inverter
Output Rectifier
R61
D1
R16 1kΩ
R17 1kΩ
R50 1kΩ
R51
R52
R53
BUF634 U10
BUF634 U11
R54
R55
Control Signal Out
J4
J5
+12
R60
Photodiode
U7 AD8304
Vlog
R38
R39
R37
R56
C7 10nF
R36
C0 1nF
C8 0.1µF
+5V
R43
R42
R44
INA128 U8
R45
R46
J3
Current/ Voltage Sense Input
R47 SR20 4-point sense resistor
J5
J6
J7