

This Application Note is pertinent to the Commander SK

Water Pressure PID Loop Control

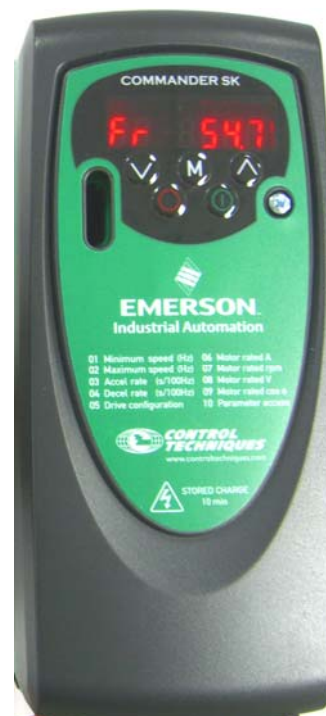
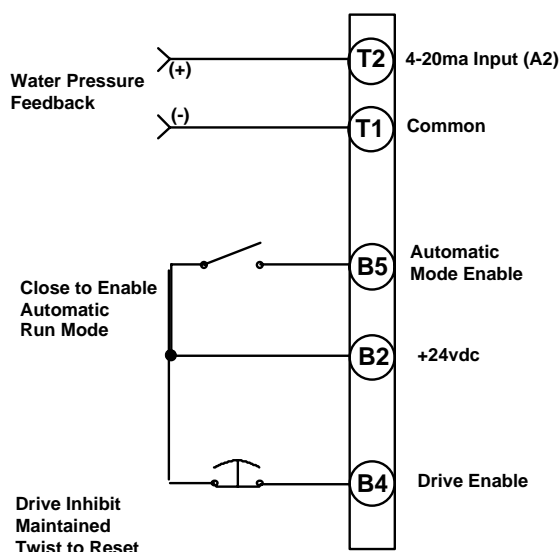
This application note will describe a way to utilize the Commander SK (note that the Unidrive SP and Commander GP may also use this setup with very minor changes to parameter settings) to regulate the water pressure in a buildings water system using the Commander SK's PID Loop Control. The drive has a "macro" that sets the PID loop automatically for "typical" applications (see parameter 05). This "macro" will not be used in this application note. The Commander SK will be programmed to start and stop itself upon pressure demands and regulate the water pressure to a specific setpoint level using its built-in PID Control Loop function (of course pressure feedback is required). This application will also provide a local control mode using the onboard Keypad. Keep in mind that although this application note discusses pump control, it could as well be a fan regulating air pressure.

Many system schemes use a rather simplistic method whereby if there is no demand for water, the pressure in the system will typically hold by running the pump at a low speed (or zero speed). This is not good for the pump or the pump motor and is not good for overall energy efficiency either. By using the Commander SK's built in Comparator function the drive will be placed in either RUN or STANDBY (Stop) based on pressure demands. When there is a demand (someone turns on a faucet) the drive will automatically go into RUN and maintain the water pressure setpoint. For set up and test, the drive can be run in keypad mode (local mode).

This application note shows how to configure the drive for this requirement. [CTSoft](#) and [CT Comms Cable](#) are required. [CTScope](#) is also useful in tuning the system.

For convenience all required parameter changes (except motor map parameters) are given both graphically and in table form.

Terminal Strip Connections



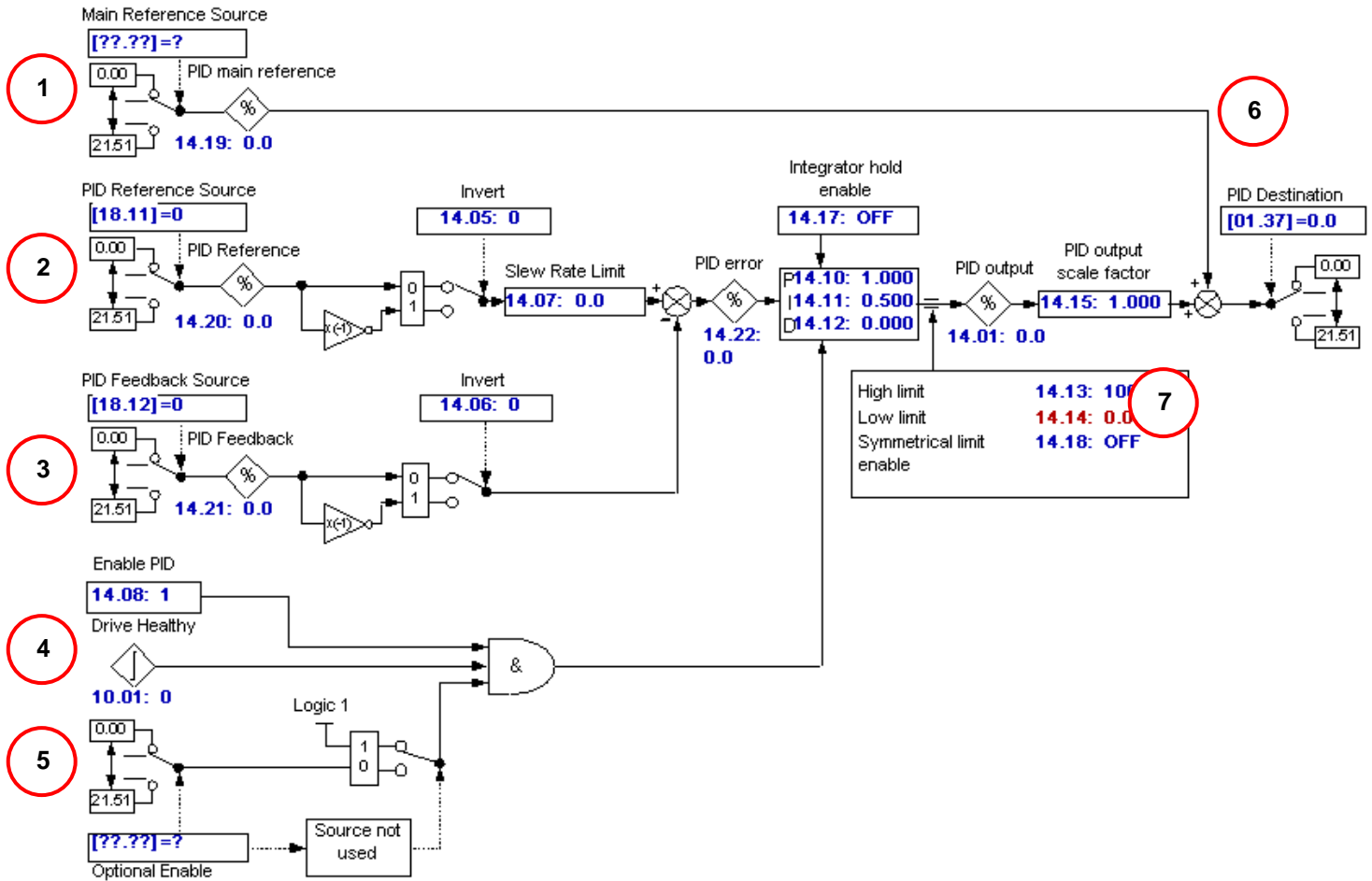
Programming

Before making any changes to the drive for the specific application, the drive should be run using the drives keypad (which is the default configuration) to verify proper operation of the drive and motor. This involves entering the basic motor information. The key parameters are the first 10 parameters. In this set up, the drive is controlled by the front keypad controls.

Parameter	Description	Default	Memory	Units
00.00	Parameter 0	0	0	
00.01	Minimum set speed	0.0	0.0	Hz
00.02	Maximum set speed	60.0	60.0	Hz
00.03	Acceleration rate 1	33.0	33.0	s/100 Hz
00.04	Deceleration rate 1	33.0	33.0	s/100 Hz
00.05	Drive configuration	PAd	PAd	
00.06	Motor rated current	0.00	0.00	A
00.07	Motor rated full load rpm	1800	1800	RPM
00.08	Motor rated voltage	230	230	V
00.09	Motor rated power factor	0.85	0.85	
00.10	Security status	L1	L1	

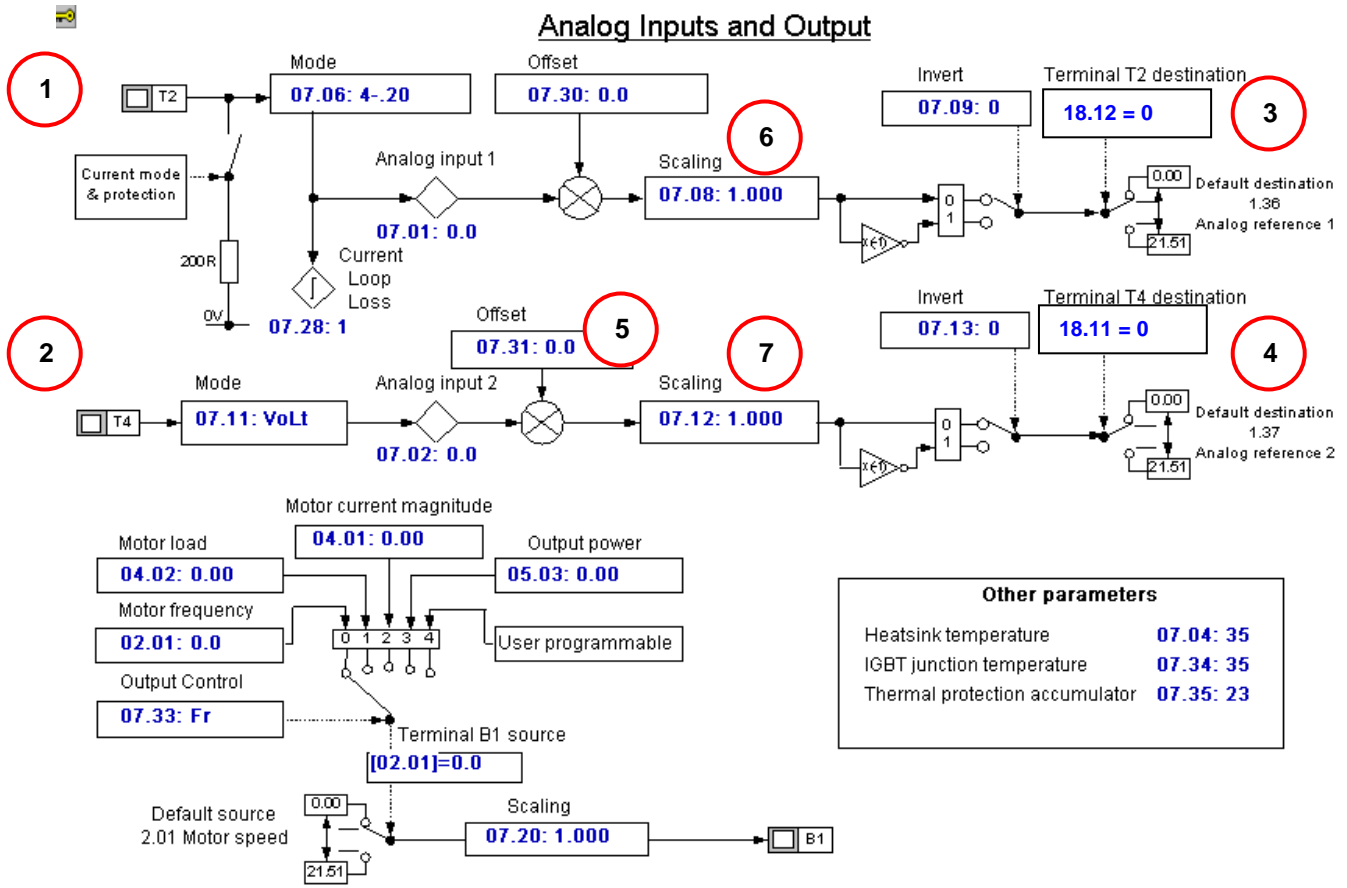
Once the drive has been successfully run, the PID can be set up. Below is the block diagram of the Commander SK's PID Loop. In this application, the main Reference Source can be ignored. All of the block diagrams are screen shots from CTSOft.

Basic PID Loop Setup



O	Parameter #	Value	Description
1	14.02	0	Main reference is not used
2	14.03	18.11	Analog reference #2 (T4) is the pressure setpoint
3	14.04	18.12	Analog reference #1 (T2) is the pressure feedback
4	14.08	1	PID circuit is enabled
5	14.09	----	Not used with automatic turn-on circuit
6	14.16	1.37	Output of the PID is sent to speed reference register 2 (#1.37)
7	14.14	0	PID is limited to forward (positive) speeds only

Analog Inputs and Output



○	Parameter #	Value	Description
1	Terminal T2	4-20 ma	4-20ma signal from water pressure sensor
2*	Terminal T4	0-10vdc	Voltage signal for water pressure setpoint, if used
3	#7.10	18.12	PID Feedback
6**	#7.08	***	Scale factor for pressure feedback
4	#7.14	18.11	PID Setpoint
7**	#7.12	***	Scale factor for setpoint
5	#7.31	0	This parameter will be used for the setpoint if the external voltage is not used. It will be mapped in menu #76
	#11.01	7.31	Parameter #61 is the digital pressure setpoint (0 to 100%)

* A 0 to 10vdc remote setpoint reference may be used (parameter #61 should be set to 0). If a digital setpoint is used (parameter #61) jumper terminal T4 to T1

** For pressure reference and feedback scaling see below.

Pressure Reference and Feedback Scaling

The two scale factors will be based on the following example.

- The pressure sensor is rated at 250 psi max. The output is a 4-20ma signal where 0 psi = 4ma and 250 psi = 20ma
- The typical pressure setpoint is in the range of 60 to 80 psi

A good working range for the feedback would be 0 to 100 psi. Since the max rating of the sensor is 250 psi, the scale factor (#7.08) would be: $250 \text{ psi} / 100 \text{ psi} = 2.5$. This will then provide a 100% feedback signal to register #18.12 at 100 psi

For the reference, parameter #7.31 is scaled 0 to +/- 100% (although we won't use the -100%). If we leave the scale factor to 1.00 (default of #7.12), 0 to 100% will correspond to 0 to 100 psi which works out nicely for this application. If we wanted to let 0 to 100% to equal 0 to 80 psi, all we would need to do is set the scale factor (#7.12) to $100 \text{ psi} / 80 \text{ psi} = 1.2$.

Therefore:

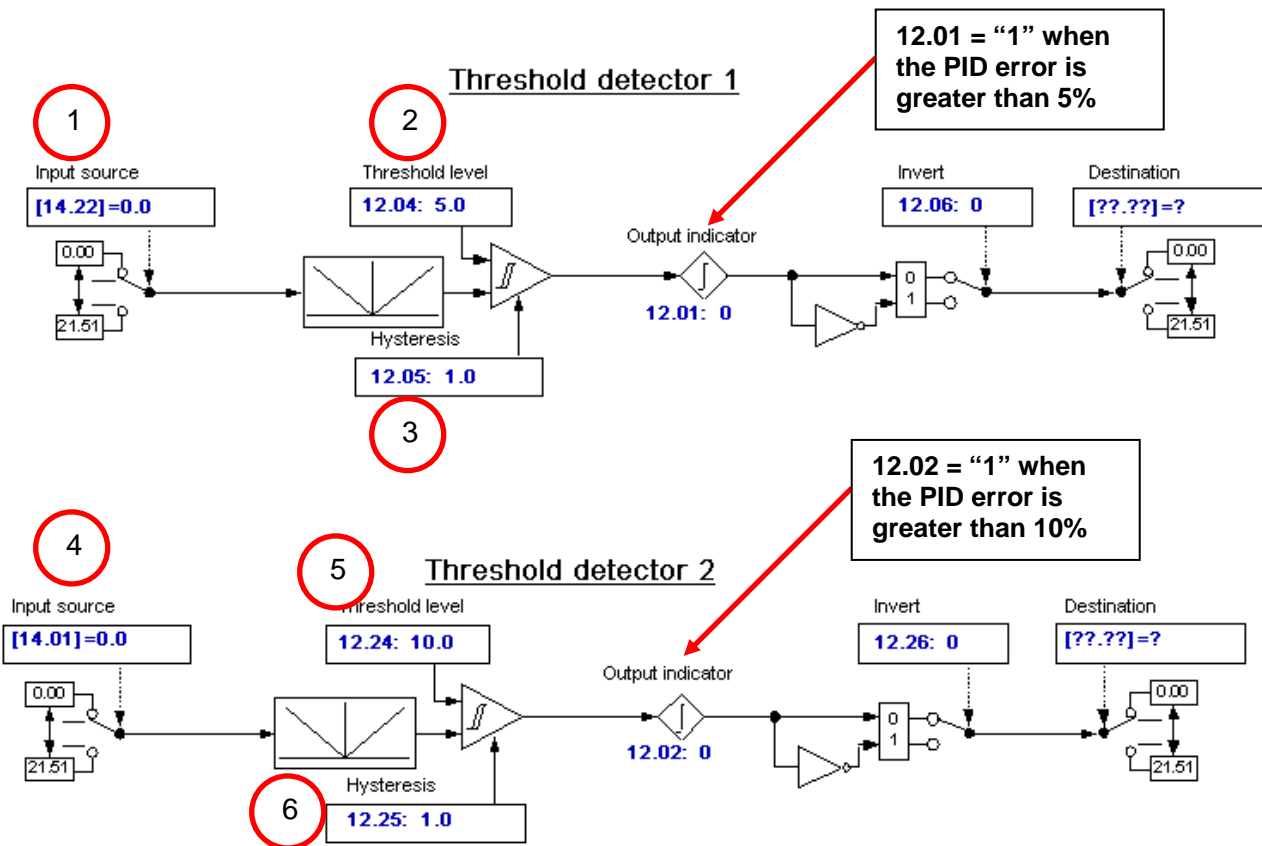
- *** #7.08 = 2.5 Scales 0 to 100 psi = 0 to 100% feedback**
- *** #7.12 = 1.0 Scales 0 to 100% setpoint to 0 to 100 psi**

Automatic Start control Circuit

In order to control starting and stopping of the drive (in automatic mode) we need to monitor certain conditions. The first of course is the PID error, #14.22, which tells us if the PID reference (pressure demand) matches the actual feedback (system pressure). If the error is less than say 5% we may not have to run the pump. This all depends upon what the output of the PID is asking for (required pump speed, not actual) . Take for instance that the error is < 5% but the PID output is 80%. This means that the PID is keeping up with the demand by running at a flow rate of about 64% of maximum, we certainly do not want to turn the pump off at this time. On the other hand, if the error is < 5% and the demanded speed is < 10% (or min speed setting in %) ,1% of max flow rate, and this condition exists for 25 seconds (which is the max time delay the standard drive can provide) we can probably turn the pump off. We will also have to override this function in the manual mode. These are the conditions we will assume for this application note.

The Comparators

The two available comparators will be set up to detect the < 5% PID error and <10% speed demand.



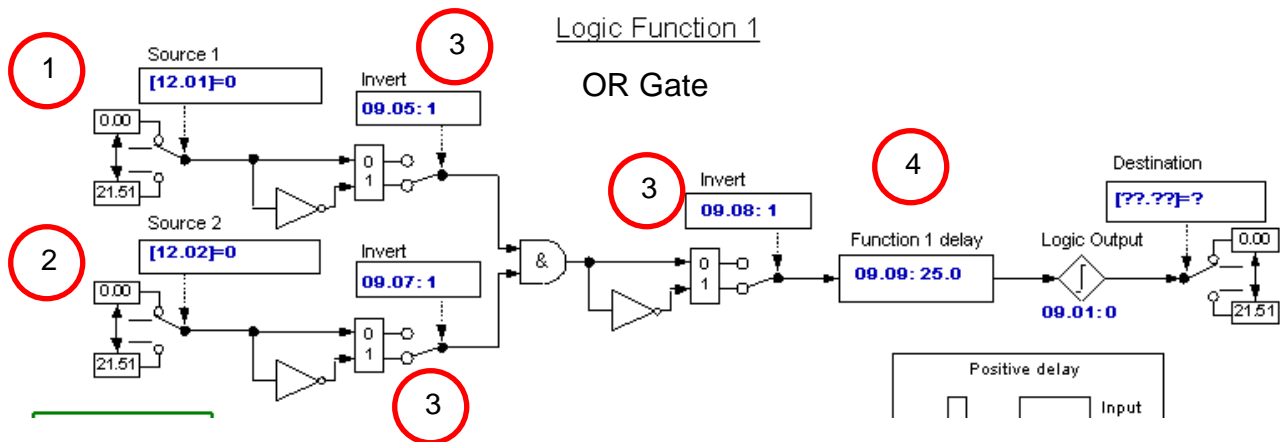
○	Parameter #	Value	Description
1	#12.03	14.22	PID error (setpoint –feedback)
2	#12.04	5	5% threshold level
3	#12.05	1	1% hysteresis
4	#12.23	14.01	PID output (automatic mode frequency / speed reference)
5	#12.24	10	PID Setpoint
6	#12.25	1	Scale factor for setpoint

The Logic Gates

In the **Automatic Mode** we will use parameter #6.15 (drive enable) to turn the drive on and off. In order to do this the drive must have the drive run and enable inputs (B4 and B5) tied to +24vdc (B2). In **Manual Mode** we will be using keypad mode using the second motor map to provide this mode change. Motor map 2 will need to be properly set up. When we switch to **Manual Mode**, parameter #6.15 must be “forced” on, otherwise the drive could be locked out by the automatic start control under certain conditions. To achieve all this, a “truth” table will be created.

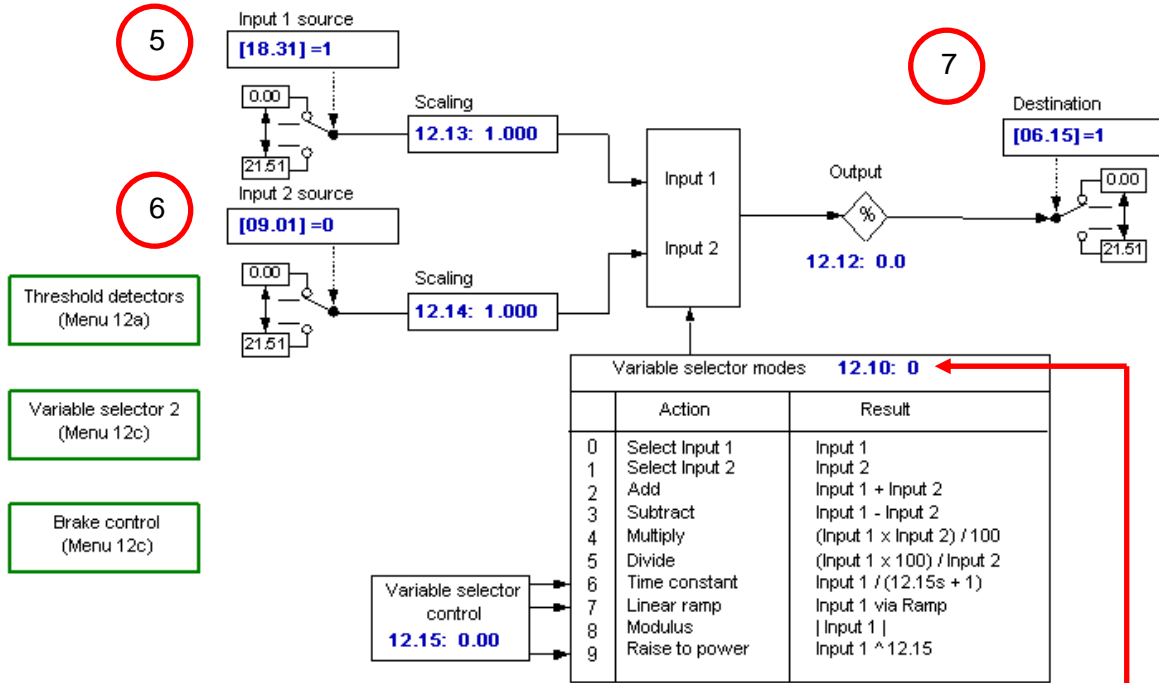
Auto / Manual (#8.03 = 1, auto)	PID error > 5% (#12.01 = 1)	PID output > 10% (#12.01 = 2)	Drive Enable (#6.15)
1	0	0	0
1	0	1	1
1	1	0	1
1	1	1	1
0	X	X	1

In looking at the “grayed” area, it is nothing more than an “OR” gate. For the function that will either “force” parameter #6.15 to a 1 in manual mode or let the states of the two comparators and “OR” gate control #6.15, we will use the Variable Selector #1 to do this. We will control the Variable Selector #1 via the Auto/ Manual input (terminal B5) and the Variable Selector #2 function and the second set of logic gates since this input must control three (3) functions; Run, Auto start control and control of which motor map is being used. Manual control will be via Drive Keypad.

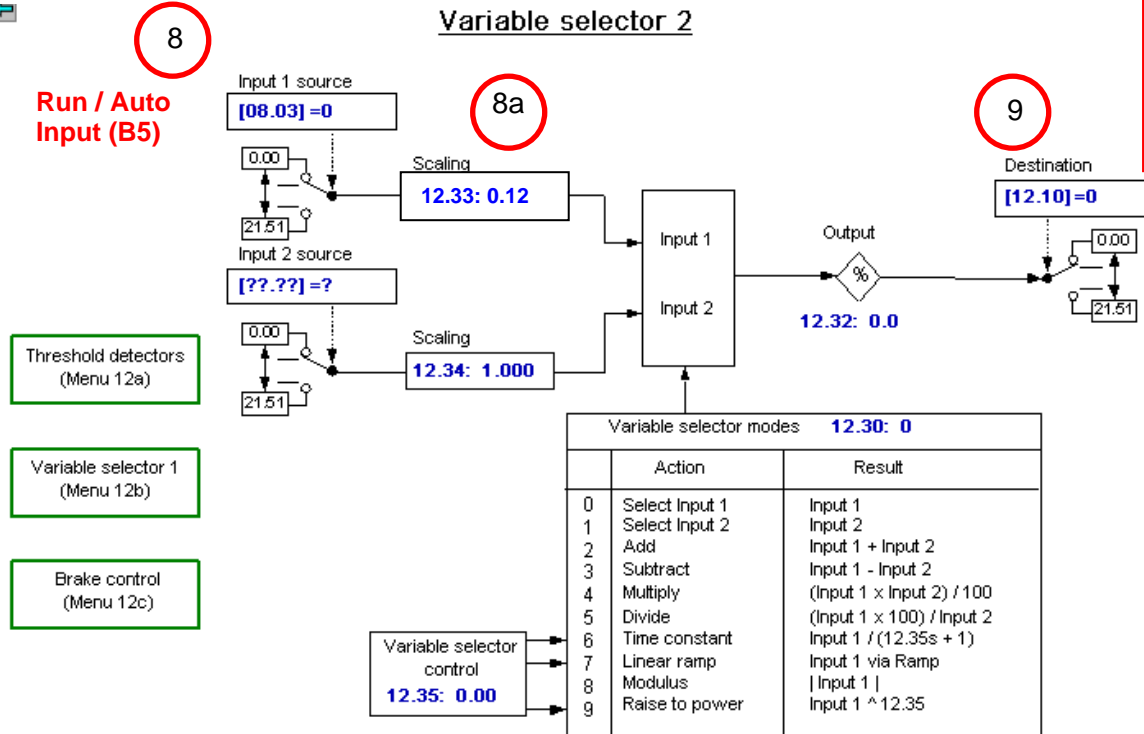


O	Parameter #	Value	Description
1	#9.04	12.01	1 = PID error > 5%
2	#9.06	12.02	
3	#9.05	ON	Setting these three parameters to “ON” create an 2 input OR Gate
3	#9.07	ON	
3	#9.08	ON	
4	#9.09	-25	25 second off delay – the system must be at less than 5% pid error and less than 10% pump demand speed for 25 seconds in order to automatically turn off

Variable selector 1

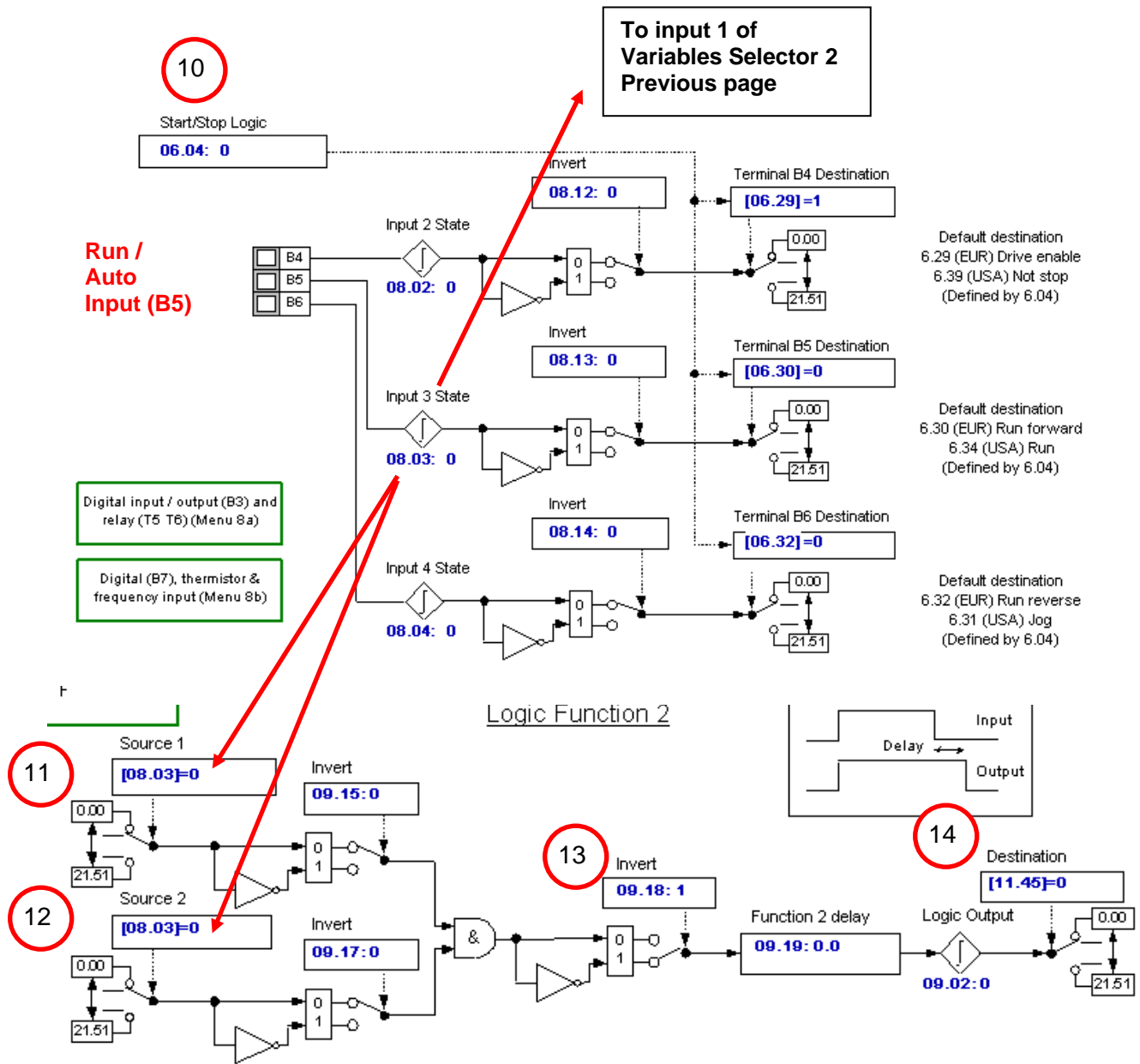


Variable selector 2



○	Parameter #	Value	Description
5	#12.08	18.31	Parameter #18.31 must be set to a "1"
6	#12.09	9.01	Automatic start control
7	#12.11	6.15	Drive enable
8	#12.28	8.03	Run / Auto input
8a	#12.33	0.12	Scale factor
9	#12.31	12.10	Run / Auto input controls Variables Selector 1

From the Auto / Manual column in the table on page 7, any time the input is a 1, we need to direct the Logic Function 1 to parameter #6.15 (drive enable), otherwise if it is a 0 we need to force it to a 1. We will achieve this by writing a 1 via parameter #18.31 and the Variable Selector #1. To do this we will use Variables Selector #2 to send parameter #8.03 (the read only bit for the Run / Auto input Terminal B5) to the control input (#12.10) of Variable Selector 1.



This page shows how the Run / Auto input (B5), besides placing the drive in the run forward mode (parameter #6.30), also selects Motor Map 1 (parameter #11.45 set to "0") and via variables selectors 1 & 2 (previous page) enables the automatic start control to control parameter #6.15 (drive enable).

○	Parameter #	Value	Description
10	#6.04	0	Start /Stop Logic set for two-wire
	#6.40	0	Non-latching Start /Stop
11	#9.14	8.03	Run / Auto input
12	#9.16	8.03	Run / Auto input
13	#9.18	ON	Invert output ON
14	#9.20	11.45	Selects Motor Map 2 when in manual mode (8.03 = 0)
	#18.31	1	

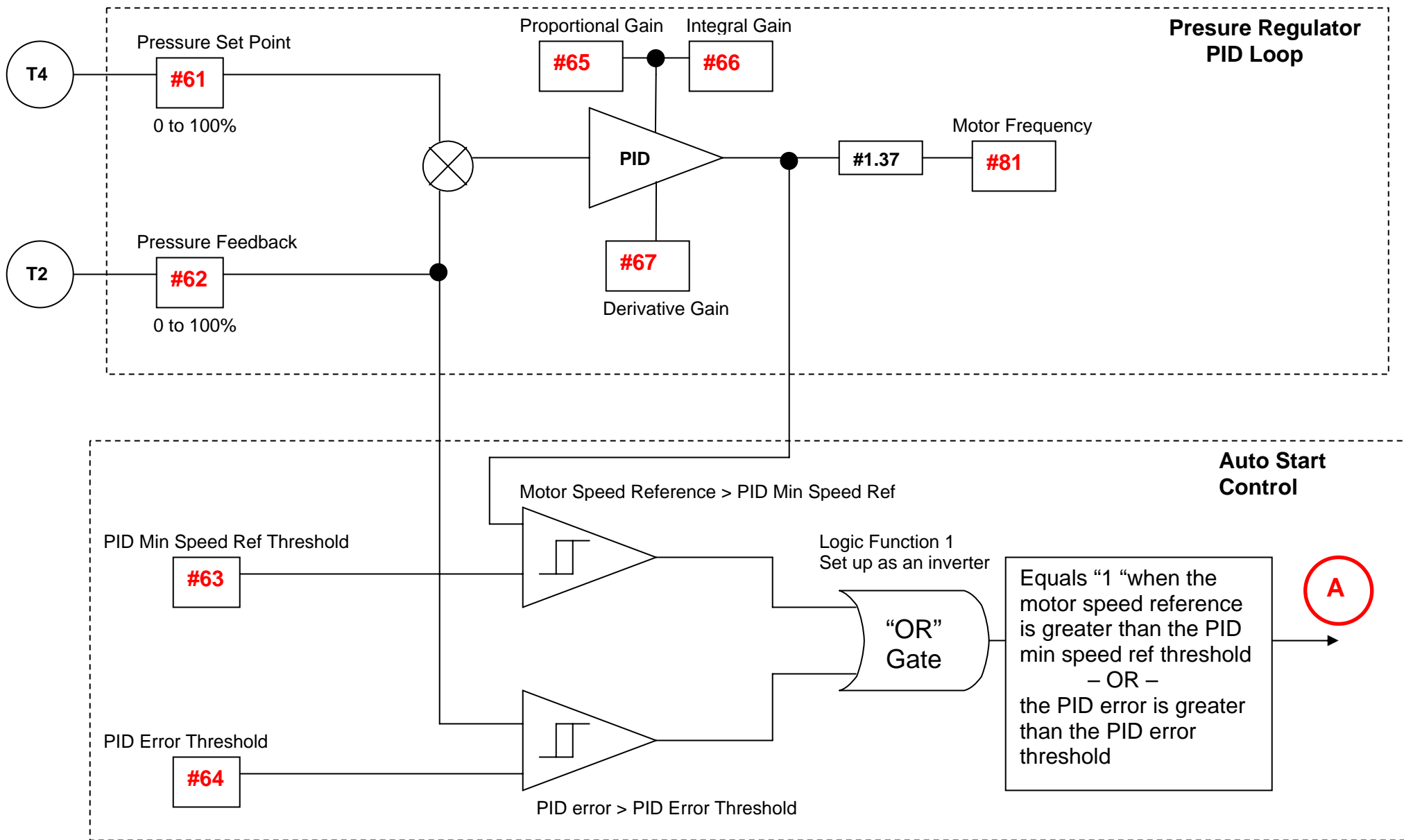
The table below shows the Motor Map parameters. Both sets should be set the same with the exception of the Drive Configuration selector. Motor Map 1 should be set for AI.AV and Motor Map 2 should be set for Pad

Open-loop mode		Motor Map 1 CommSK	Motor Map 2 CommSK
Maximum speed	01	1.06	21.01
Minimum speed	02	1.07	21.02
Drive configuration Reference selector	05	11.27	21.03
Acceleration rate	03	2.11	21.04
Deceleration rate	04	2.21	21.05
Motor rated frequency	39	5.06	21.06
Motor rated current	06	5.07	21.07
Motor rated full load RPM	07	5.08	21.08
Motor rated voltage	08	5.09	21.09
Motor rated power factor	09	5.10	21.10
Number of poles	40	5.11	21.11
Stator resistance	--	5.17	21.12
Voltage offset	--	5.23	21.13
Thermal time constant	--	4.15	21.16
Symmetrical current limit	--	4.07	21.29

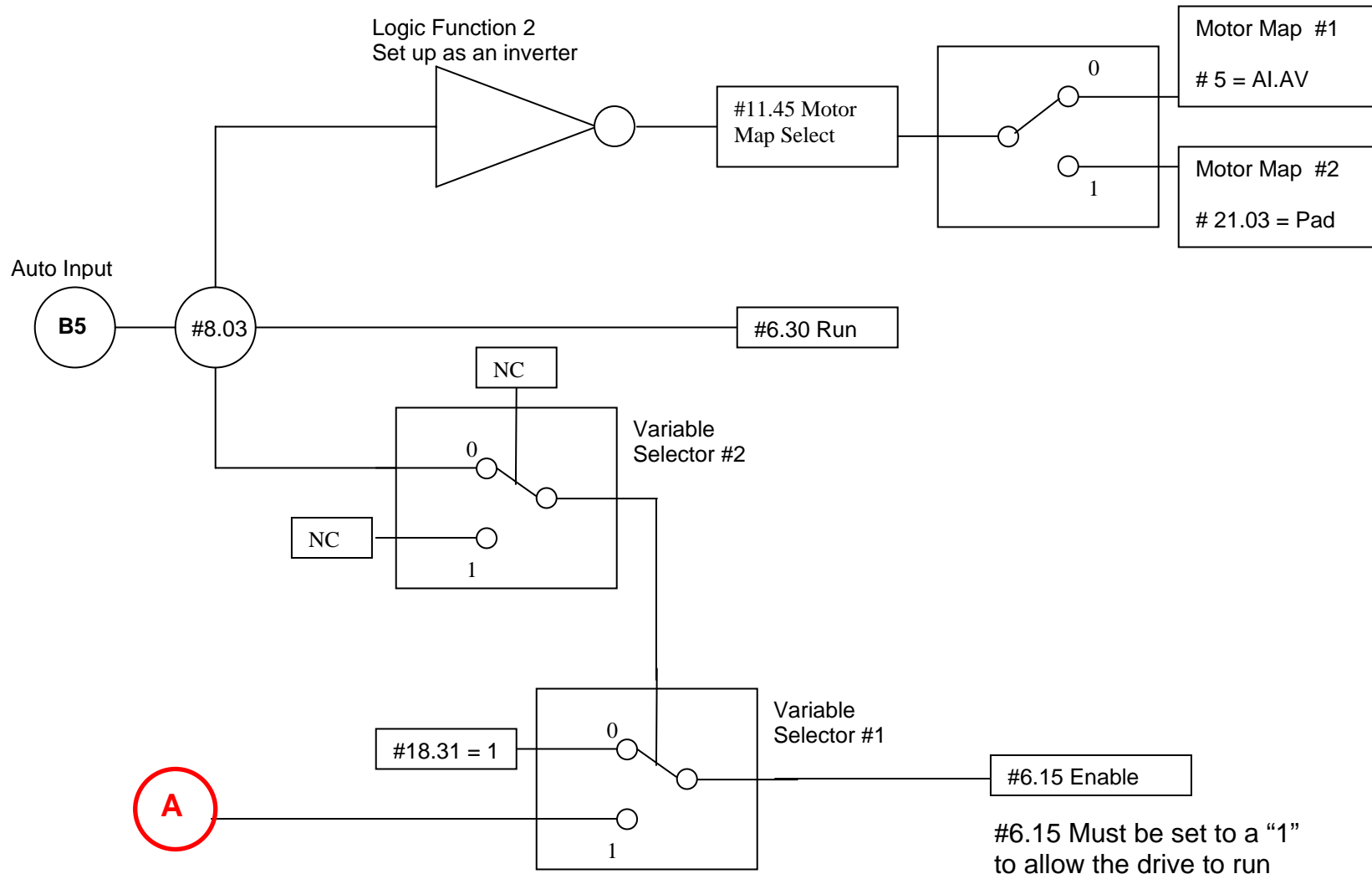
These parameter changes allow the PID loop settings to be monitored and adjusted from the 60's parameters on the drive keypad.

Function	Menu 70 setup	Menu 60 adjust
PID Pressure Setpoint 0 100%	#11.01 = 7.31	61
PID Pressure Feedback 0 to 100% (read only)	#11.02 = 14.21	62
PID output minimum speed threshold	#11.03 = 12.24	63
PID error threshold	#11.04 = 12.04	64
PID Proportional Gain	#11.05 = 14.10	65
PID Integral Gain	#11.06 = 14.11	66
PID Derivative Gain	#11.07 = 14.12	67

System Block Diagram Sheet #1



System Block Diagram Sheet #2



Restoring Parameter to a replacement drive (or cloning a second drive of the same size)

When the drive is operating as required, the program should be uploaded and saved as a parameter file (not project). To restore it to a new / replacement drive, use the procedure below:

1. Open CTSOft ,select SK and then :”Detect Drive Settings”
2. Open the saved parameter file
3. Download the file into the drive
4. Reset drive and save parameters to drive
5. Open the saved parameter file -- AGAIN
6. Download the file into the drive
7. Reset drive and save parameters to drive
8. Now you can go online with the drive to monitor or make changes.

Remember to upload and resave parameter file if changes are made.

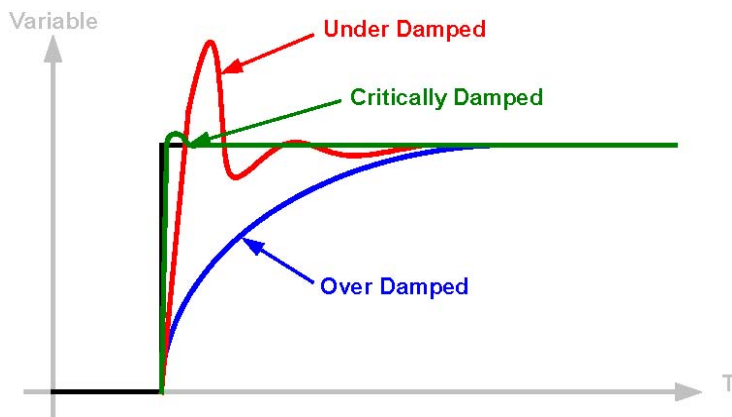
If you are using the **Memory Stick** or the **Logic Stick** for backup, you must “read” the stick twice.

PID tuning

Using different values of these two gains, you can tune the response of the PID controller to suit the system. If the system is “Hunting” by overshooting and undershooting, the system is said to be Under Damped.

If the system takes a long time to reach the setpoint, then the system is Over Damped.

The ideal is to have the system critically damped (see diagram below). As each system is different, trial and error using the Proportional and Integral gains to tune the system to a critically damped state is required.



[CTScope](#) (click on CTScope to download program) is an ideal tool to use for tuning the PID loop .

Questions: Ask the author ??

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