

# PID Tuning – Application Note



## LDD-130x:

LDD-1301

LDD-1303

**meerstetter  
engineering** 

 Member of Berndorf Group



Developed, assembled, and tested in Switzerland

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# 1 Introduction

The Meerstetter laser diode driver family LDD-130x can drive a variety of loads on its output with different electrical characteristics and limits. There are many configuration parameters to help achieve this. The current is controlled by a configurable PID controller implemented on the microcontroller.

This document serves as a guide to tune the laser diode driver (LDD) for optimal performance. This is an advanced topic, please read the setup guide and the user manual first. This application note assumes that you have set up your laser diode driver correctly with a working load connected to its output. For the initial tests, it is recommended that you use a test load with a similar forward voltage to your laser and a current clamp to monitor the output current.

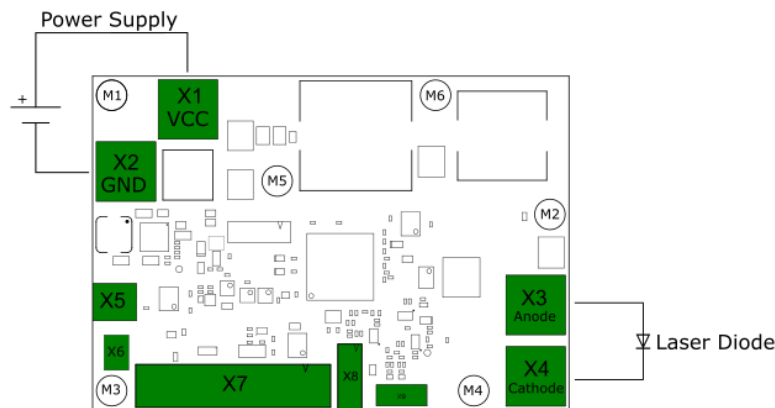


Figure 1. LDD-1301 setup

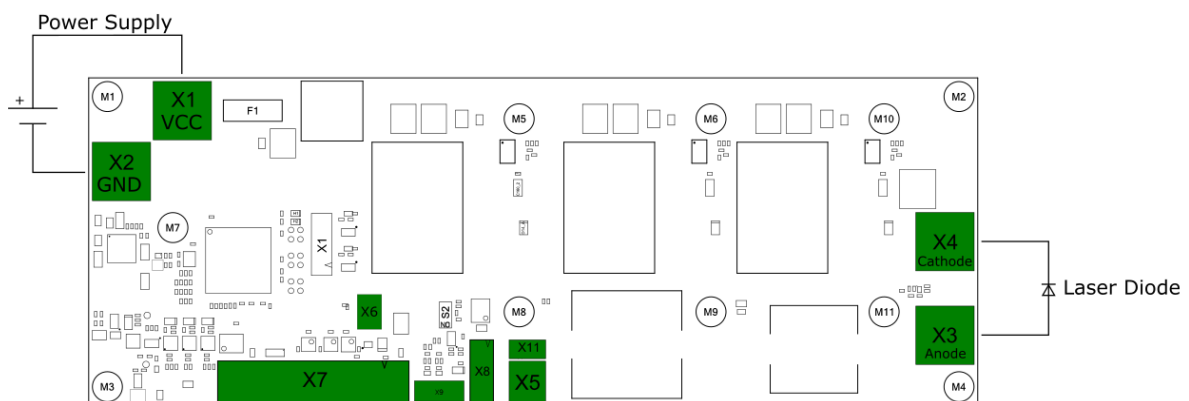


Figure 2. LDD-1303 setup

## 2 Service Software

Start the LDD-130x Service Software and connect to the device. The settings relevant to the PID controller are located in the “Current Controller Settings” section of the “Operation” tab. In chapter 3 [PID Tuning](#), these settings are used to optimise the behaviour of the current controller.

LDD-130x Service Software V 2.10

Monitor Operation Light Power Control Lookup Table Sign

Input Source Selection

|                         | Actual      | New                              |
|-------------------------|-------------|----------------------------------|
| Output Enable           | OFF         | <input type="button" value="v"/> |
| Nominal Output Current* | Set Current | <input type="button" value="v"/> |

Nominal Output Current Values

|                 | Actual | New                  |
|-----------------|--------|----------------------|
| Set Current [A] | 0      | <input type="text"/> |

Current Controller Settings

|                   | Actual  | New                  |
|-------------------|---------|----------------------|
| PID Kp [%/A]      | 0.16    | <input type="text"/> |
| PID Ti [s]        | 5.5E-05 | <input type="text"/> |
| PID Td [s]        | 1E-05   | <input type="text"/> |
| Slope Limit [A/s] | 10      | <input type="text"/> |

Output Stage Limits

|                             | Actual | New                  |
|-----------------------------|--------|----------------------|
| Max Nominal Current [A]     | 0.5    | <input type="text"/> |
| Min Nominal Current [A]     | 0      | <input type="text"/> |
| Current Error Threshold [A] | 0.6    | <input type="text"/> |
| Voltage Error Threshold [V] | 10     | <input type="text"/> |

Figure 3. Current Controller Settings in the LDD-130x Service Software

## 3 PID Tuning

The default current controller settings are designed to be safe as long as the limits are properly set, however, tuning the parameters can help reduce overshoot and/or the current rise time. If the default current controller configuration suits your needs, there is no need to tune the parameters.

Caution must be taken when configuring the PID settings. Albeit damage to the laser diode driver is unlikely the load may get damaged by overshoot current if the laser diode driver is configured improperly. Furthermore, the controller may not be able to stabilize the current if the parameters are chosen incorrectly. This can be mitigated by setting the output limits and error threshold as strictly as possible before adjusting the PID parameters.

### 3.1 Understanding the PID Controller

The laser diode driver usually drives a non-linear load whose characteristics are also affected by external factors such as temperature. A PID controller is used to control the current output of the laser diode driver. PID controllers react to changes by applying a proportional, an integral and a derivative error correction component which correspond to the three letters P, I and D.

#### 3.1.1 PID Parameters

##### 3.1.1.1 $K_p$

P stands for the proportional part of the controller, which corrects errors by applying an error correction value proportional to the amount of deviation. The parameter is the proportional factor  $K_p$  which is the most straightforward of the PID parameters. It is simply multiplied with the error value.

##### 3.1.1.2 $T_i$

The I part of the controller integrates past error values and helps to eliminate a constant deviation from the set nominal current. The parameter  $T_i$  is the time the controller integrates values over. It is used to correct steady errors that are not caught by the proportional part of the controller. A large  $T_i$  can make the output very slow changing.

##### 3.1.1.3 $T_d$

D is the derivative part of the controller. It derives the error value and as such can help reduce the overshoot as it counters the proportional response. Its tuning parameter is  $T_d$ . A large  $T_d$  slows down the current controller and excessive  $T_d$  values can lead to an unstable controller with oscillations of the output current.

#### 3.1.2 Other Parameters

##### 3.1.2.1 Slope Limit

The last parameter of the current controller is the slope limit. It specifies the maximum allowed rate of change of the output current. It should be set as low as possible, according to the requirements of the application. This allows for more aggressive PID settings.

## 3.2 PID Tuning Approach

To figure out the optimal PID parameters for a specific load we can follow a method, and/or optimize by trial-and-error.

The setup described in Figure 4 and Figure 5 is used to measure the voltage and the current at the output of the LDD.

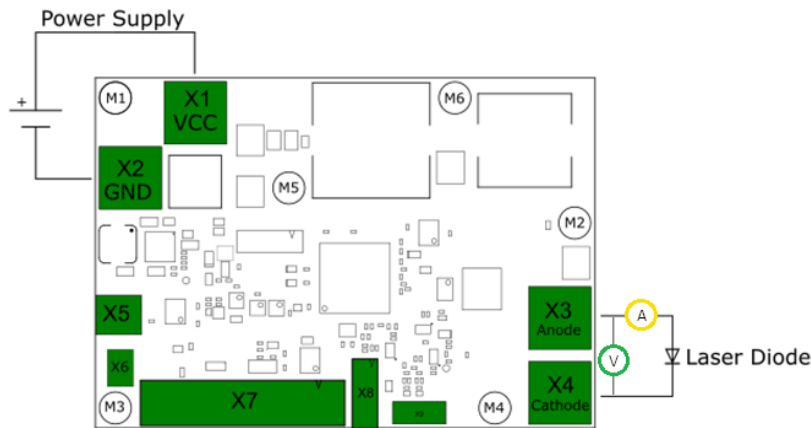


Figure 4. LDD-1301 setup with measurement probes on output: yellow: CH1, green: CH2

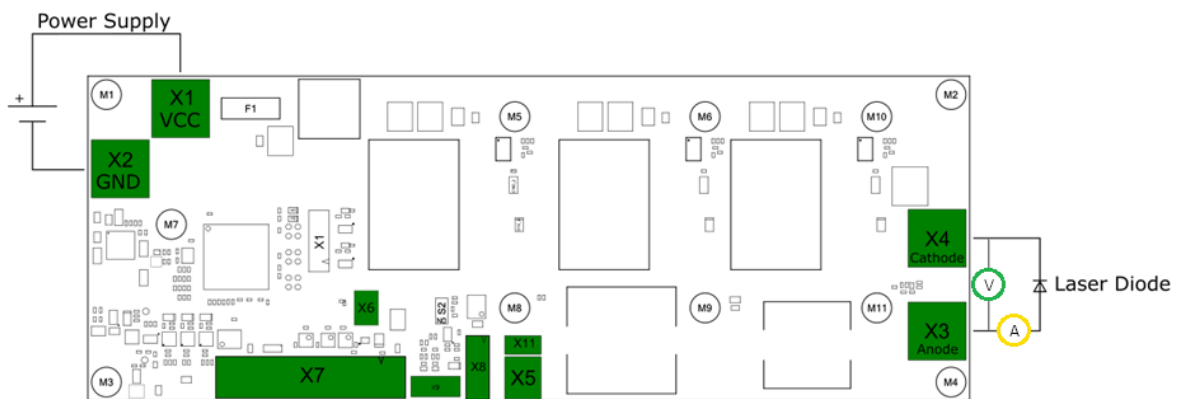


Figure 5. LDD-1303 setup with measurement probes on output: yellow: CH1, green: CH2

It is recommended to start from the default PID parameters specified in the ini file shipped with the service software. Furthermore, make sure the slope limit is large enough for your desired rise time.

Optimization is load specific, the parameters below only apply to the load used in this example. You will have to perform the optimization on the load you intend to use.

Our starting point is the rather slow default PID configuration. Figure 6 shows how the current controller reacts to a change of the nominal current setpoint.



Figure 6. Default PID  
( $K_p=0.16\text{ \%}/A$ ,  $T_i=5.5E-05\text{ s}$ ,  $T_d=1E-05\text{ s}$ , Slope Limit = 10 A/s)

One approach is to tune the PID parameters using the Ziegler-Nichols method:

1. Make sure your LDD is set up and the output current limits are set as restrictive as possible.
2. Find the ultimate gain  $K_u$  by increasing  $K_p$  until the output begins to show stable oscillations as can be seen in Figure 7.

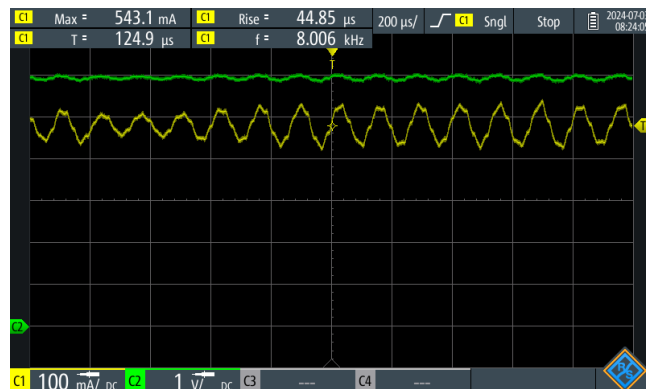


Figure 7. Stable oscillations obtained, used for  $K_u$  and  $T_u$

$$K_u = K_p = 1.17$$

$$T_u = 125 \mu s$$

3. Write down the  $K_u$  value, it is used to calculate the final  $K_p$ .
4. Write down the oscillation period duration  $T_u$ , it is used to calculate  $T_i$  and  $T_d$ .
5. Follow the table below to configure your PID values:

| $K_p$             | $T_i$             | $T_d$             | Description              |
|-------------------|-------------------|-------------------|--------------------------|
| $0.60 \times K_u$ | $0.50 \times T_u$ | $0.12 \times T_u$ | Original Ziegler-Nichols |
| $0.33 \times K_u$ |                   | $0.33 \times T_u$ | Reduced overshoot        |
| $0.2 \times K_u$  |                   |                   | No overshoot             |

6. If you are not satisfied with the behavior of the PID after you have performed all steps above, then proceed with the **PID Fine Tuning** described below.

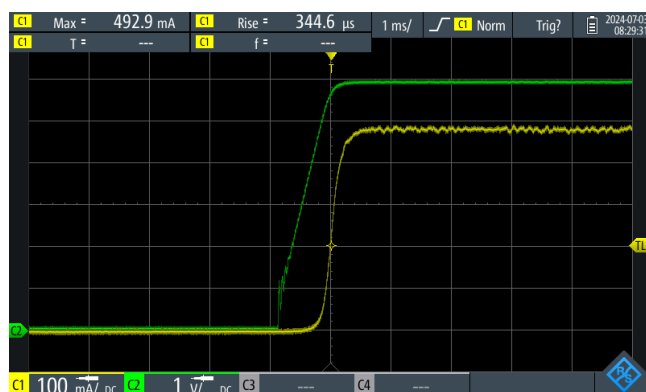


Figure 8. PID optimized using the Ziegler-Nichols method

$$K_p = 0.7 \text{ \%}/A$$

$$T_i = 6.25E-05 \text{ s}$$

$$T_d = 1.5E-05 \text{ s}$$

### 3.2.1 PID Fine Tuning

If the PID behaviour does not suit your needs yet you can perform some fine tuning of the PID parameters:

- Increase  $K_p$  and decrease  $T_i$  until the output starts to oscillate or the output delay/rise time is short enough.
- Increase  $T_d$  to avoid overshoot.  $T_d$  can also be set to zero which disables the D component.
- Make sure the slope limit is not the limiting factor. See [Figure 18](#) in chapter 4 [Examples](#).

Optimizing for a small  $T_i$  usually yields better results than optimizing for a large  $K_p$ . Reducing  $K_p$  may allow for a smaller  $T_i$  resulting in faster PID control.

Consult the following table for common PID misconfiguration issues:

| Cause                   | Effect                                      |
|-------------------------|---------------------------------------------|
| $K_p$ too small         | large delay                                 |
| $K_p$ too large         | overshoot + oscillation                     |
| $T_i$ too small         | oscillation                                 |
| $T_i$ too large         | slow, large delay                           |
| $T_d$ too small or zero | may overshoot, $T_d$ is not always required |
| $T_d$ too large         | oscillation                                 |

## 4 Examples

In this part we show some visual examples of the effects of various current controller configurations. CH1 measures the output current while CH2 measures the output voltage. Note: this is a current controller which means CH1 is the variable controlled by the PID. See [Figure 9](#) and [Figure 10](#) for probe connections.

The PID parameters used are only applicable to the specific load used for the example and will most likely not apply to your load. All measurements are done with the LDD-1303, however, the same concepts apply to the LDD-1301.

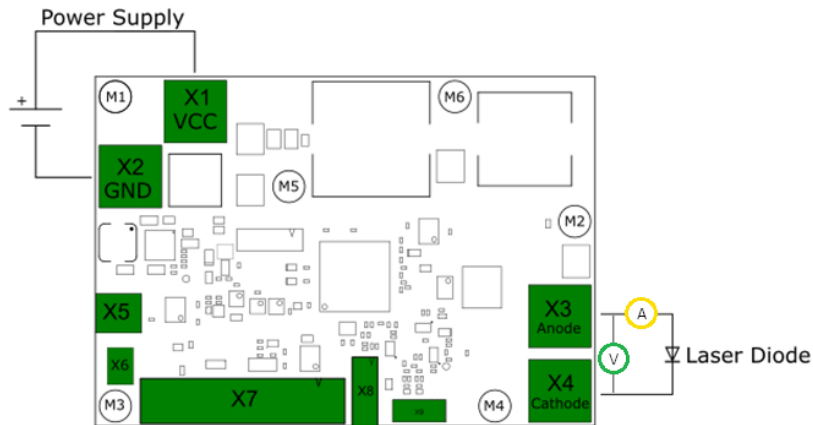


Figure 9. LDD-1301 setup with measurement probes on output  
yellow: CH1, green: CH2



Figure 10. LDD-1303 setup with measurement probes on output  
yellow: CH1, green: CH2

Figure 11 shows an example of the desired output after tuning. Notably there is no overshoot and a short delay.

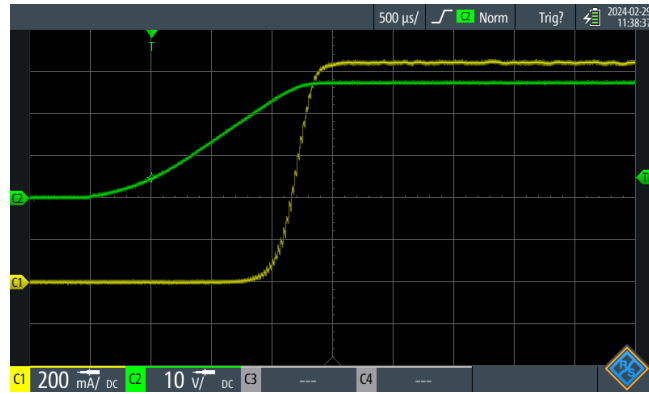


Figure 11. Good current controller configuration, the output has fast response times and manages to stabilize afterwards ( $K_p=0.16$ ,  $T_i=0.00001$ ,  $T_d=0$ , Slope Limit=1000)

The following examples show what happens if the current controller is misconfigured.

A side effect of a high  $T_i$  value as it becomes more dominant is that the output becomes inert, that means that oscillations disappear, but the initial signal rise time becomes larger. Other than that, there are no adverse effects of a large  $T_i$  component. Meanwhile, a too small  $I$  component can cause a steady state error between the actual current and the target current and it can even cause the controller output to oscillate.

Figure 12 shows the effect of a high  $T_i$  value and Figure 13 shows the effect of a low  $T_i$  value.

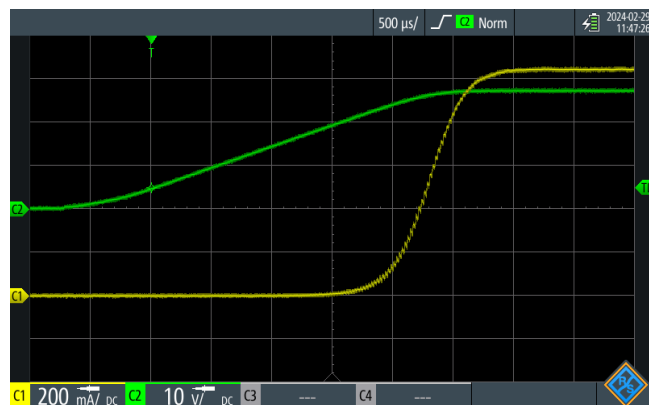


Figure 12. Doubled  $T_i$ , slow ( $K_p=0.16$ ,  $T_i=0.00002$ ,  $T_d=0$ , Slope Limit=1000)

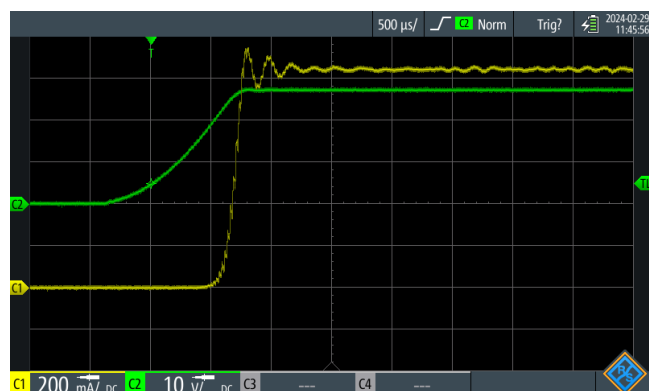


Figure 13. Halved  $T_i$ , smaller delay, oscillating / overshoot ( $K_p=0.16$ ,  $T_i=0.000005$ ,  $T_d=0$ , Slope Limit=1000)

Furthermore, as shown in [Figure 14](#), if  $T_i$  is too low and  $K_p$  too high the output may become unstable.

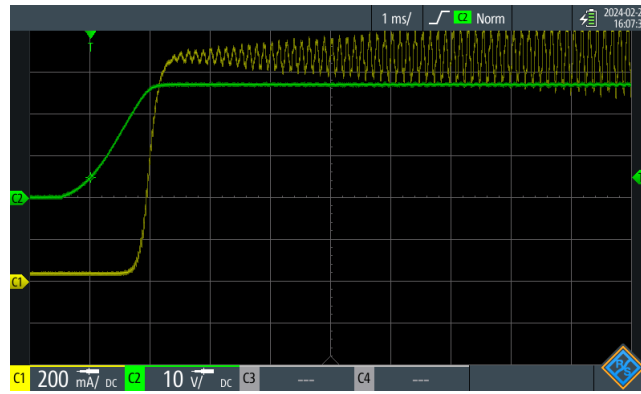


Figure 14.  $K_p$  too high and  $T_i$  too low ( $K_p=1$ ,  $T_i=0.00005$ ,  $T_d=0$ , Slope Limit=1000)

$T_d$ , while often not required can predict the trend of an error and prevent overshoots.

[Figure 15](#) shows the effect of  $T_d$ .

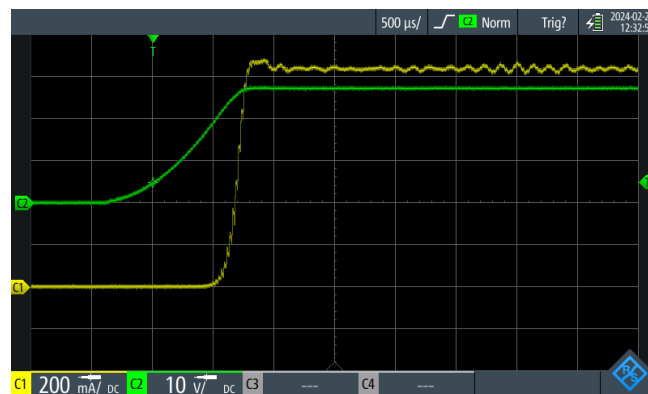


Figure 15. Halved  $T_i$ ,  $T_d=0.0002$ , overshoot reduced ( $K_p=0.16$ ,  $T_i=0.000005$ ,  $T_d=0.0002$ , Slope Limit=1000)

$K_p$  defines the general step size and a too low  $K_p$  can cause a slow output while a too high  $K_p$  can lead to an unstable signal or an overcurrent.

[Figure 16](#) shows the effect of a slightly too high  $K_p$ .

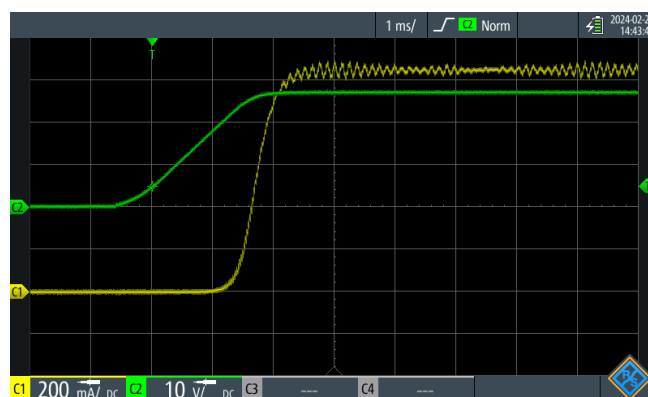


Figure 16. Output keeps visibly oscillating.  $K_p$  too high ( $K_p=1.1$ ,  $T_i=0.0001$ ,  $T_d=0$ , Slope Limit=1000)

$T_d$  should be used with caution. A too high  $T_d$  value will cause an unstable output because it starts to pick up and amplify small changes. See [Figure 17](#).

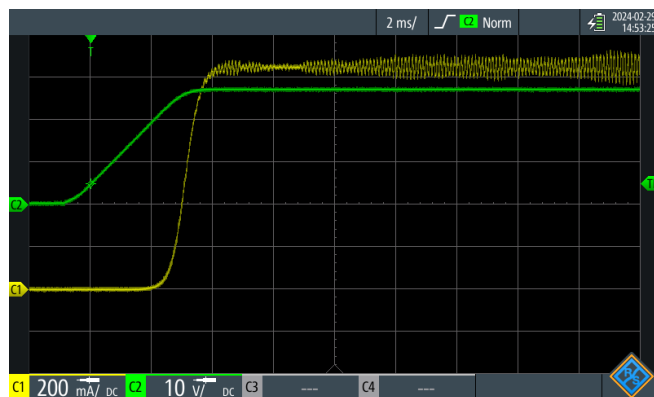


Figure 17.  $T_d$  too high, output no longer stable ( $K_p=0.6$ ,  $T_i=0.0001$ ,  $T_d=0.000075$ , Slope Limit=1000)

The slope limit can be used to slow down the rate of change of the output current. However, if it is set too restrictive, it might slow down the change of the output too much as seen in [Figure 18](#).

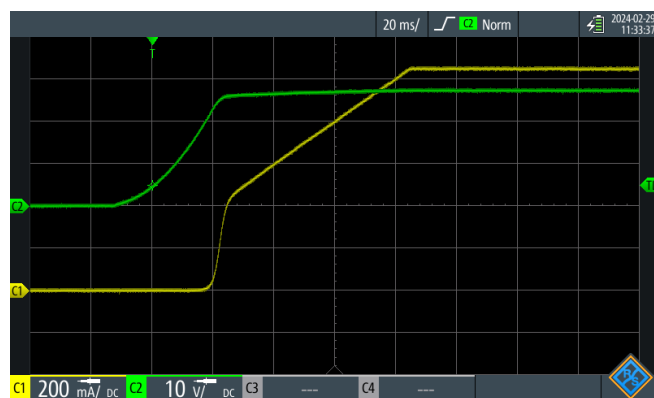


Figure 18. low slope limit, output is slow, large delay ( $K_p=0.16$ ,  $T_i=0.00001$ ,  $T_d=0$ , Slope Limit=10)

## 5 Default Values

Depending on your use case the default PID parameters may completely suffice. Those values were chosen to work in a wide variety of situations but may be slow since they lack tuning for a specific purpose. See [Figure 19](#) and [Figure 20](#).

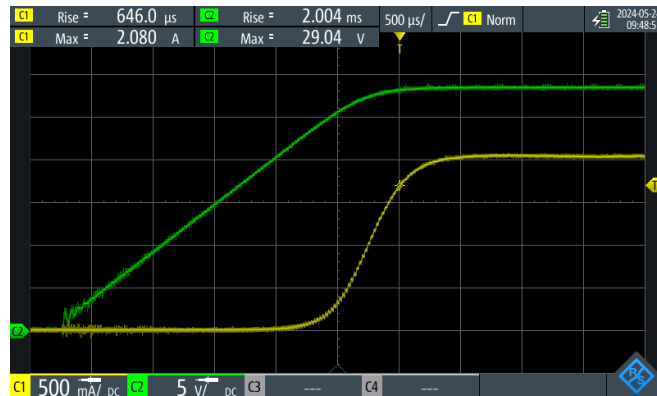


Figure 19. Default PID without slope limitation ( $K_p=0.16$ ,  $T_i=0.000055$ ,  $T_d=0.00001$ , Slope Limit= $10^{12}$ )



Figure 20. Tuned PID without slope limitation ( $K_p=0.2$ ,  $T_i=0.000025$ ,  $T_d=0.00001$ , Slope Limit= $10^{12}$ )

## A Change History

| Date of change | Doc/Version | Changed/<br>Approved | Change / Reason                                                                                                                 |
|----------------|-------------|----------------------|---------------------------------------------------------------------------------------------------------------------------------|
| 24 May 2024    | A           | SC / RS              | <ul style="list-style-type: none"><li>• Initial release</li></ul>                                                               |
| 17 July 2024   | B           | SC / RS              | <ul style="list-style-type: none"><li>• Add: Ziegler-Nichols method</li><li>• Add: diagram to show measurement points</li></ul> |
| 09 Sept 2024   | C           | SC / MLO             | <ul style="list-style-type: none"><li>• Mod: Make LDD-130x agnostic</li></ul>                                                   |