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PLEXON®
Neurotechnology Research Systems

Optogenetic Controller

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Optogenetic Controller

User's Guide December 2012

CAUTION: THIS OPTOGENETIC CONTROLLER IS NOT FOR USE IN HUMANS

CAUTION: READ THE ENTIRE MANUAL BEFORE ATTEMPTING TO OPERATE THIS EQUIPMENT

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This user's guide is PN 08-06-A-56-P11

This user's guide refers to:

Hardware	PN 08-06-A-04
Firmware	PN 08-06-A-32
Software version	1.0.0

Printed in the United States of America

Table of Contents

1 Getting Started

Before using your Optogenetic Controller, please check www.plexon.com/downloads.html for any software updates.

2 Introduction

The Plexon® Optogenetic Controller is a 4-channel current or voltage output device. It has 4 individually programmable channels that can be configured from a host computer using the Radiant graphical user interface software or configured from user-written applications by means of a software development kit (SDK). The maximum output of the Controller is up to 1100mA in current mode or 5V in voltage mode. User defined output limits may be defined with 8-bit precision and output waveforms may be defined with 8-bit resolution within those output limits.

Playback of pulses and arbitrary stimulation waveforms may be initiated from the host PC or triggered in response to external digital inputs. Each channel has a dedicated start and stop digital inputs that may be used to initiate and halt stimulation. Each channel also has four dedicated digital outputs to signal to other devices the precise time when stimulation events are occurring.

Thank you for purchasing this Plexon product. We hope you are pleased with every aspect of it. Please do not hesitate to contact us if you have any questions.

3 System Requirements

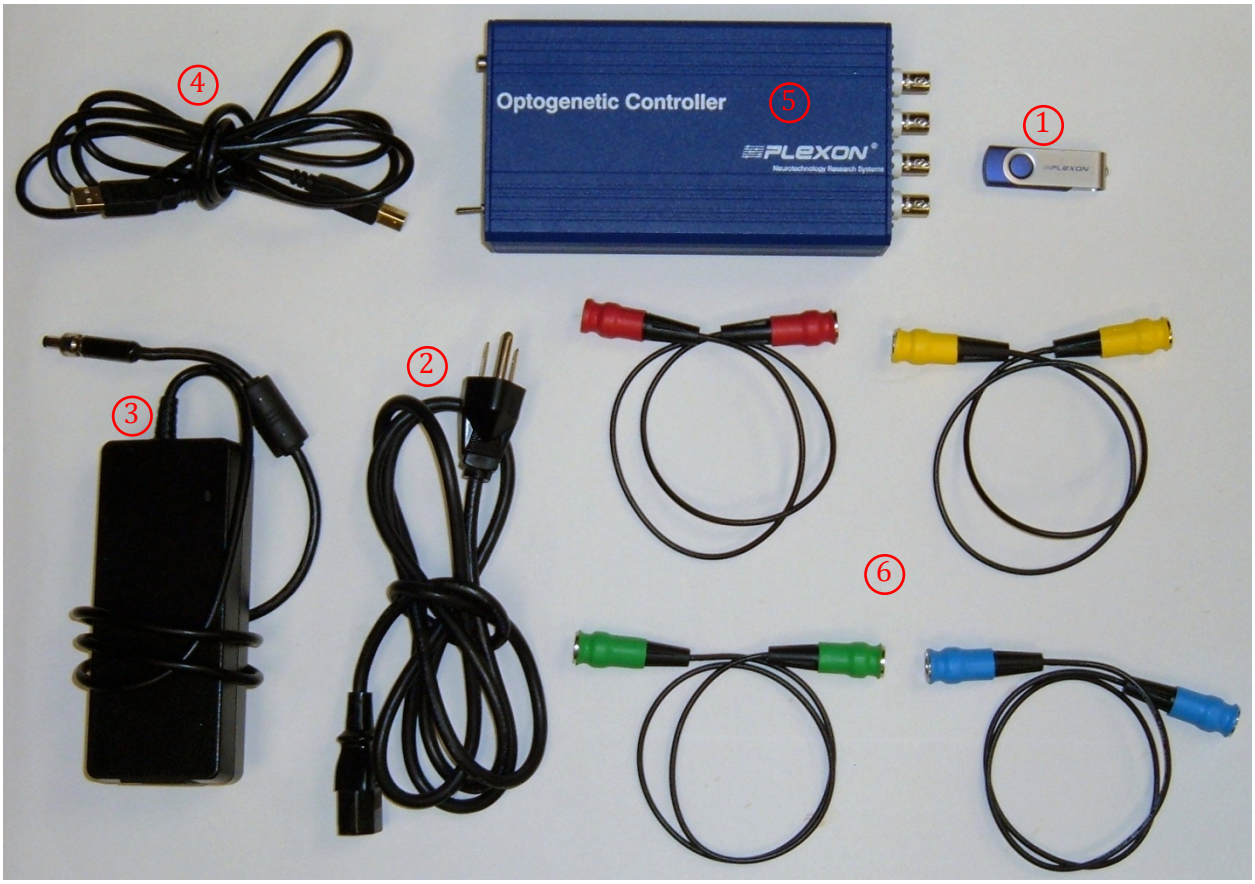
A modern personal computer running Windows 7 or Windows XP with a free USB 2.0 port and 1 GB of memory is required to operate the system.

4 System components

When you receive your Plexon Optogenetic Controller, confirm that you have the following pieces:

1.	USB memory with software & drivers	Plexon	
2.	AC power cord (7.5 ft)*	Volex	17250 10 B1
3.	Power Supply	Plexon	08-06-A-37
4.	USB Cable (2m)	Monoprice	5438
5.	Optogenetic Controller	Plexon	08-06-A-04
6.	Color-coded Insulated BNC Cables (4)	Plexon	06-03-A-04-CCLL

* International customers: The stimulator power supply has an International Electrotechnical Commission (IEC) 60320 C14 inlet for AC power (shown below). The AC power cord supplied with the stimulator has an IEC 60320 C13 connector and a NEMA 5-15 plug compatible with the AC wall outlets in North America. Users in other regions must supply a power cord with an IEC 60320 C13 connector and a plug that is compatible with the AC wall outlets in the region of use.



5 Installation

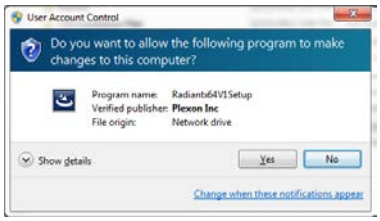
Read the entire installation section before proceeding with the installation. Follow the installation steps in the order that they are presented. Install the software first, followed by the hardware. Do not connect the controller to an implant until you have read the entire manual.

5.1 Software Installation

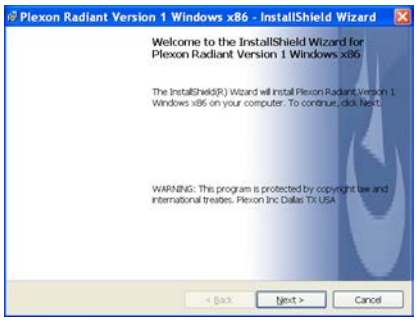
Read the entire Software Installation section before proceeding with any of the steps.

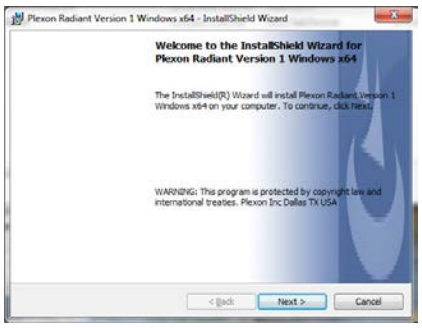
5.1.1 Browse to the \Optogenetic Contrller\Radient_x64 or \Radient_x86 folder on the USB flash drive depending on if you have a 64 or 32 bit operating system

5.1.2 Right-click the file Radientx86v1Setup.exe or Radientx64v1Setup.exe and select Run as Administrator to begin the installation process. On some computers, you will get a warning:



5.1.3 Click Yes or Run to continue. The welcome screen appears:





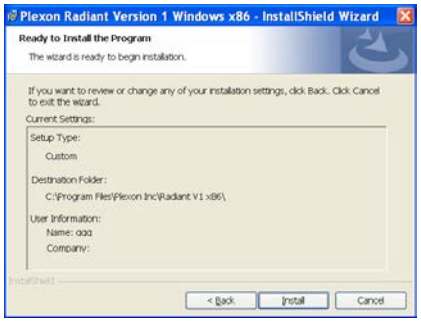
If the software is already installed, then the welcome screen gives you the option to repair (re-install) or remove the software as shown on the right above. If the software is not already installed, then the welcome screen shown above on the left appears.

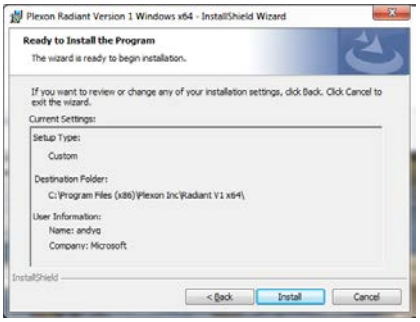
Click Next to continue.

5.1.4 Read and accept the Plexon End User License Agreement

Click Next to Continue

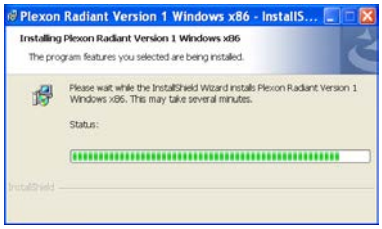
5.1.5 You will be asked to confirm where the files will be stored:

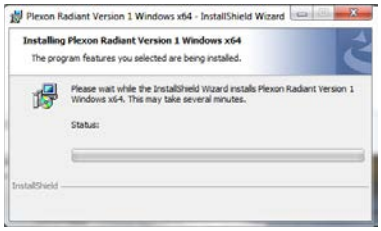




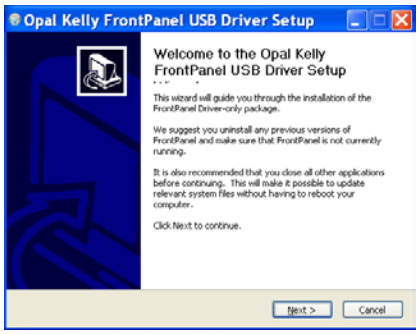
Click Next to continue.

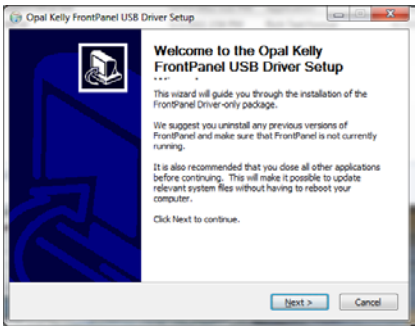
5.1.6 When the installation begins, it may take a couple of minutes before the progress bar begins moving across the window. This is especially true in Windows 7:





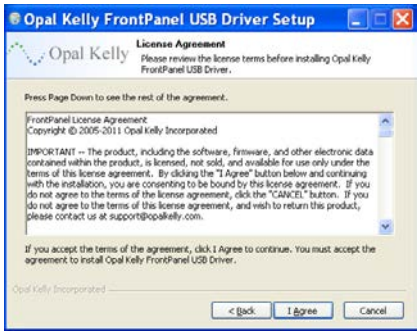
5.1.7 An Opal Kelly FrontPanel USB Driver Setup window will pop up.

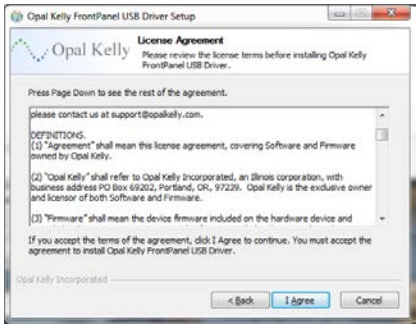




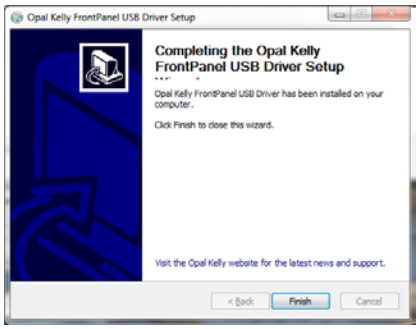
Click Next

5.1.8 Accept the Opal Kelly License Agreement

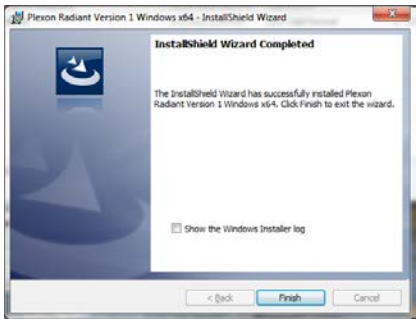




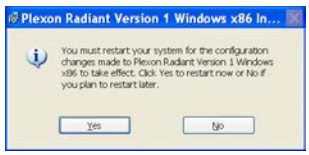
5.1.9 Click Finish When the Opal Kelly Driver Setup is complete.

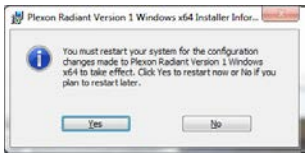


5.1.10 Click Finish in the Plexon Radiant installation window



5.1.11 The computer will have to be restarted to complete the installation.





5.2 Hardware Installation

Read the entire Hardware Installation section before proceeding with any of the steps.

An oscilloscope is highly recommended for viewing the output of the channels in voltage mode.

5.2.1 Connect the AC power cord between the AC outlet and the power supply.

5.2.2 Connect the DC power cord between the power supply and the Optogenetic Controller.

5.2.3 Connect the USB cable between the Optogenetic Controller and the computer.

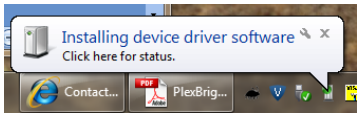
5.2.4 Connect the BNC cable between the Optogenetic Controller channel 1 and the Oscilloscope.

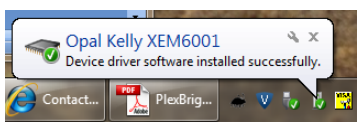
5.3 Turning on the power for the first time

5.3.1 Flip the power switch to the on position. The LED next to the switch on the end of the Optogenetic Controller should illuminate.

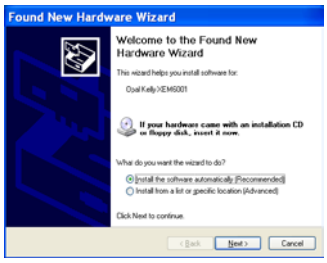
5.3.2 The first time you turn the stimulator on a "Found New Hardware" balloon will appear in the lower right hand corner of the computer screen. In Windows 7, the balloon changes from "Installing device driver software" to "Opal Kelly XEM6001". In Windows XP, the Found New Hardware Wizard will appear. Choose Install the software automatically. After it is finished, the balloon will change to "Your new hardware is installed and ready to use."

Windows 7:





Windows XP:



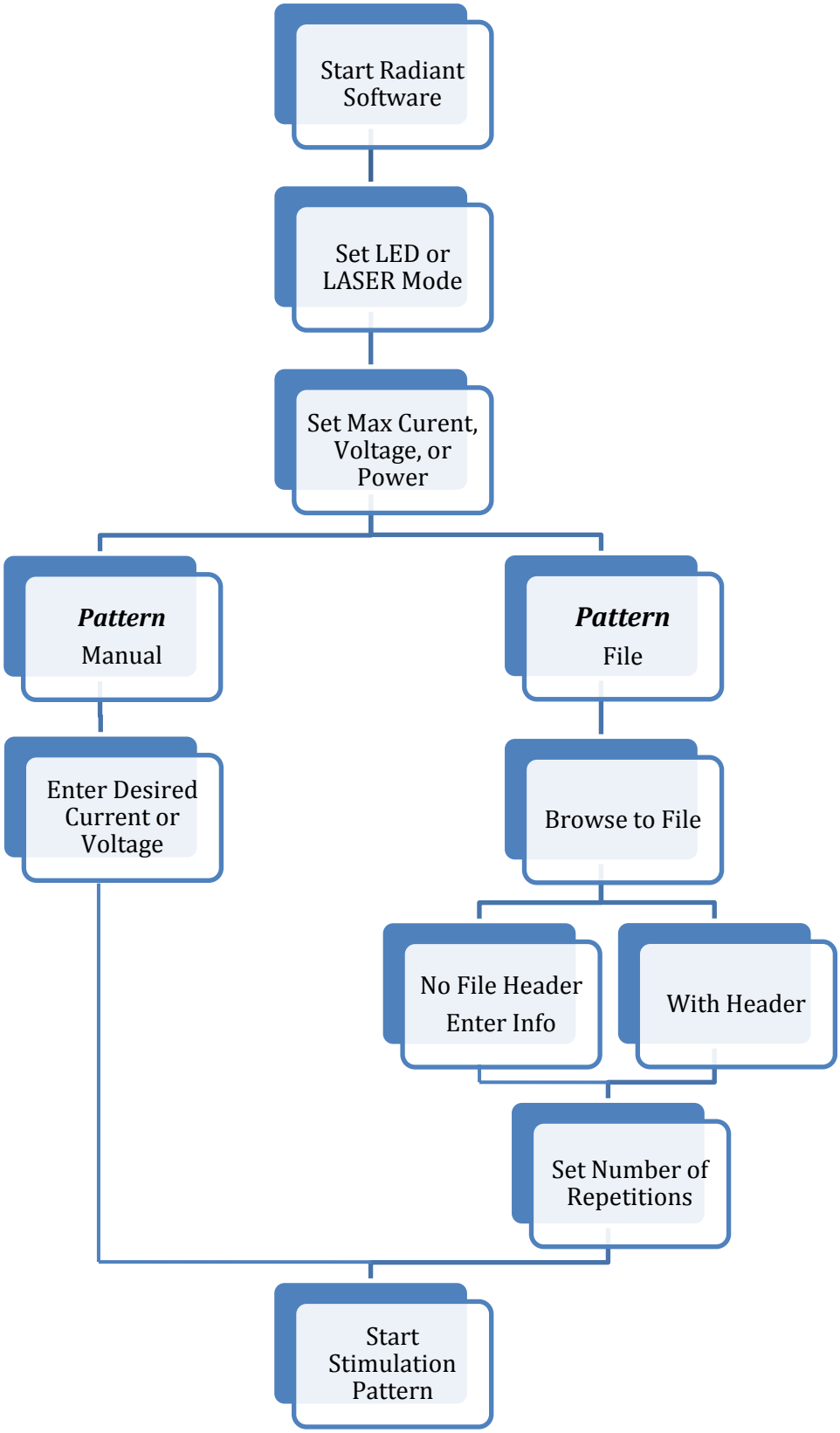
6 Getting Started

This section introduces the basic functions of the Optogenetic Controller and guides you through basic operation using the voltage mode. Voltage mode is intended to be used to control lasers with a 0-5V control input. The current mode functions similarly for controlling LEDs, but it is more difficult to quantify the output without a light meter. It is highly recommended that you work through this section before attempting to do any type of stimulation. Note that you will need an oscilloscope to see the output.

6.1 Overview

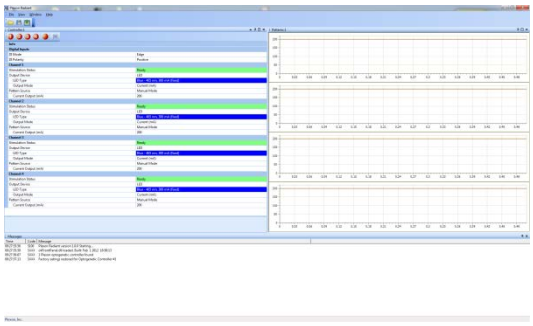
Every optogenetic stimulation protocol begins with the definition of the stimulation pattern. The graphical user interface (GUI) provides a means for manually setting the output value or loading a stimulation pattern from a user-created text file. Once defined, the stimulation pattern is downloaded into the controller memory for playback. Playback can be initiated from the GUI, SDK, or in response to a digital input to the controller hardware.

6.2 Operational Flowchart



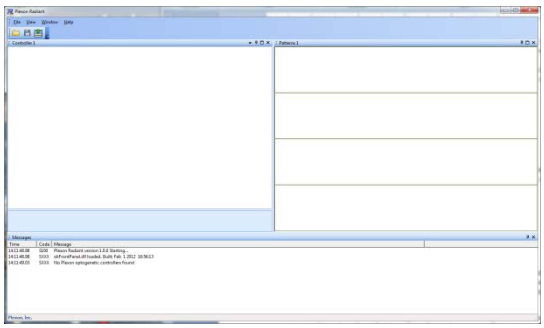
6.3 Launching the Radiant software

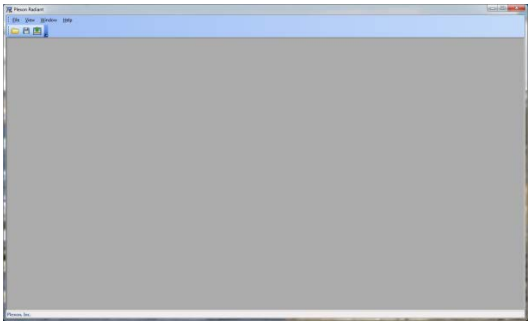
Make sure all of the Optogenetic Controllers are connected to the computer and turned on. Up to four controllers can be used with a single computer. Then launch the Radiant software by double clicking on the desktop icon. You should see the factory default graphical user interface as shown in the figure below. Note that the number of controllers that are connected will determine the number of tabs in the bottom left of the screen. Also, the LEDs on the end panel of the controller will indicate the device number 1~4.



Hint: You may load the factory default configuration at any time by clicking File – Restore Factory Settings.

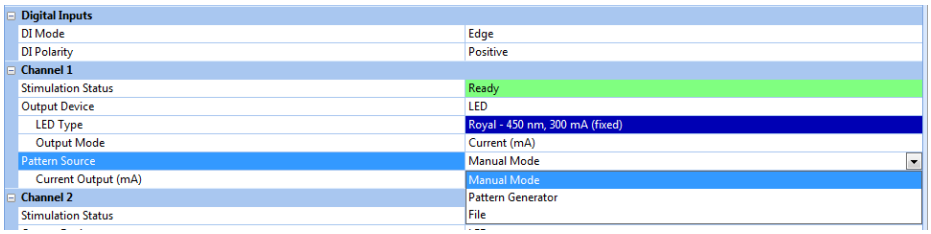
Note that if the USB cable is not connected to the controller or if the controller power is turned off when the software is started, the software will open but there will be no window to input stimulation parameters, as seen on the left below. If you see the window on the right and your stimulator is connected, it is possible that your layout has changed. Go to Window – Layout – Reset to Default Layout.





6.4 Using manual mode to use the controller

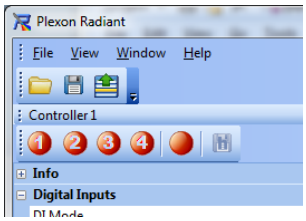
The fastest and easiest way to use the controller is in manual mode. This is the mode that the software will start in by default the first time the software is run. If it is not in manual mode, you can select it by clicking the drop down menu next to Pattern Source.



Begin by using a BNC cable to connect the output marked CH 1 to an oscilloscope. Next, set the Output Device to Laser and the Voltage Limit to 5000mV. Then click in the box below Manual Mode to and move the slider to 1000 (mV).

Hint: Fine incremental changes can be made to the slider value using the up and down arrow keys or the scroll wheel on your mouse.

When you press the start button for channel 1 in the upper left, the output voltage will change to 1V.

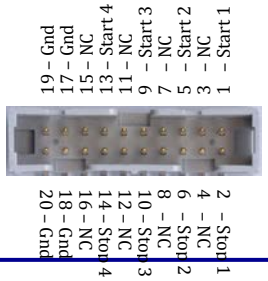


Once the channel is running, you can adjust the slider to change the output voltage. The output will remain at the set voltage until you stop the channel or change the value.

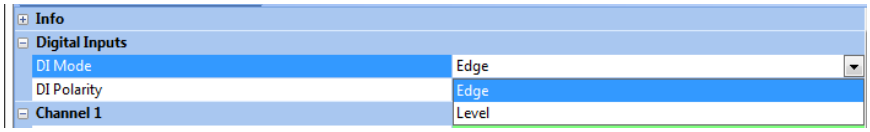
6.5 Starting and Stopping Stimulation

There are two ways to start playing a stimulation pattern: with the host PC through software and with a hardware digital input. Note that a pulse started from software can be stopped with a digital input and vice versa. In software, until a pattern for a channel has been defined, the start button in the top left of the interface is grayed out. As soon as the pattern has been selected, the start button becomes active. At that point, the channel can be triggered to start. To initialize stimulation from the software, you can click the start button for the individual channel. Alternatively, the start all button (to the right of channel 4's start button) can be clicked and every channel that has been configured will start at the same time. Once clicked, the start button changes functionality to become a stop button.

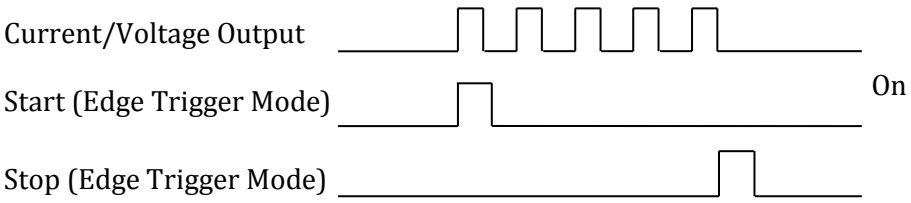
In hardware there are start and stop TTL-compatible digital inputs for each channel. Inputs should range from 0 – 5 V. Inputs <0.8V are logic "0" and >2.0V are logic "1". The pinout for the Digital In connector is shown below.



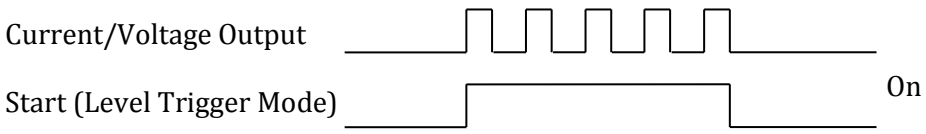
The digital inputs can be operated in two different modes. To select the mode, click the drop down menu next to DI Mode at the top of the screen.



The first mode is called Edge mode. In this case, a rising edge on the start pin initiates stimulation, and a rising edge on the corresponding stop pin stops stimulation. If the stop input comes in the middle of a stimulation pattern, the pattern will be cut short. Stimulation will also stop if the pattern plays to completion. This is illustrated below.

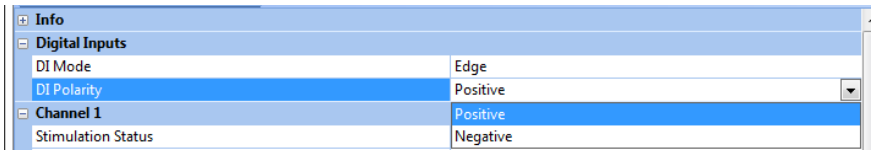


The second mode is called Level mode. In this mode, the stimulation pattern starts when the Start input transitions from 0 to 1, and continues until the pattern is complete or the Start input transitions from 1 to 0. This is illustrated below.



As before, if the Start digital input goes low in the middle of a pattern, the pattern will be cut short. A start signal that occurs after a pattern has been cut short will resume playback of the pattern. When a stimulation pattern plays to completion, the Radiant software will automatically re-load the pattern in preparation for another start signal. However, the process of detecting the end of the pattern and re-loading the pattern takes some time and it may be on the order of 100 ms before the pattern is ready to be triggered again.

There are two ways to set the polarity of the digital inputs: Positive and Negative. These can be accessed from the drop down menu DI Polarity at the top of the screen.



In Positive mode, the controller responds to a rising edge if the inputs are in edge mode, or to a logic 1 in level mode. This is the more common method of communicating through TTL. In Negative mode, the controller responds to a falling edge if the inputs are in edge mode, or to a logic

0 in level mode. Care should be taken when changing polarity as it is possible to inadvertently start stimulation. For example, the digital inputs are pulled low, so if the polarity is set to negative with no input connected all channels that are ready will start when the polarity is changed from positive to negative.

6.6 Defining a pattern with a .txt file

Stimulation patterns can be defined in simple text files using any text editor software (Microsoft Word, Notepad, etc.). More advanced users can programmatically create files using software such as Matlab or Labview.

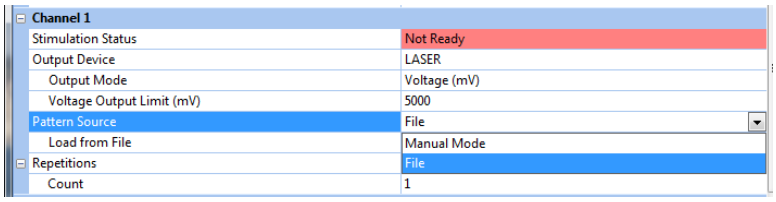
The text file is simply a list of amplitudes that is updated every 100µs. To maintain a value longer than 100µs, the value is repeated. Several sample files are included in the installation package.

The amplitude units can be binary (0-255), mA, mV, or mW. The user specifies the units when loading the text file.

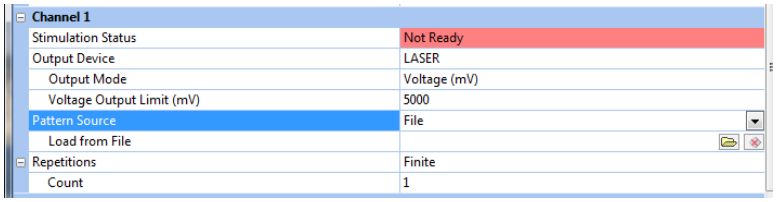
6.7 Loading a pattern from a .txt file

First set the Output device as LASER, output mode as Voltage (mV), and Voltage Output Limit (mV) to 5000.

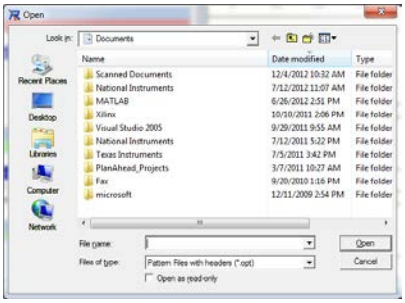
Begin by selecting File from the Pattern Source drop down menu.



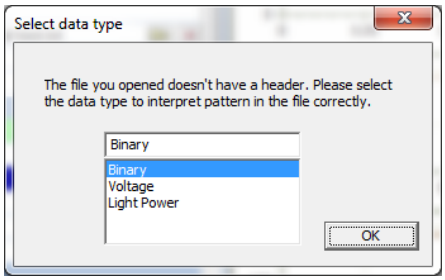
Next click on the folder in the field next to Load from File.

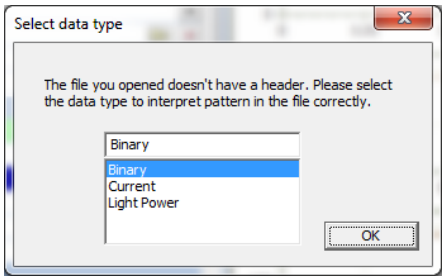


A dialog box will pop up. There are two types of files (.opt and .txt). A .opt file has a header that defines stimulation parameters such as units, while a .txt file is just a series of amplitudes.



Select the file pulse_bursts.txt that is located at C:\Plexon Data\Sample Pattern Files. Note that the pattern files are Read Only. To change them, first copy and rename the original and then remove the Read Only flag by right clicking the file name and selecting Properties from the drop down. One of the dialog boxes below will appear depending on whether LASER or LED is selected for the Output Device. With Laser selected, you will see the dialog box on the left.

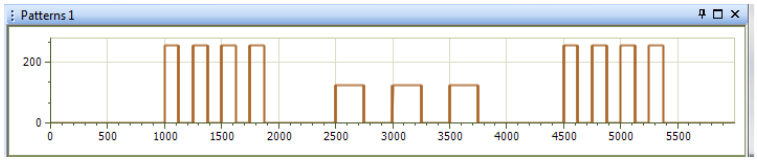




Next you will select the units. Binary is a value from 0-255 which outputs a value from 0-max. Voltage is represented in mV, Light Power is represented in mW, and Current in mA. Select Voltage.

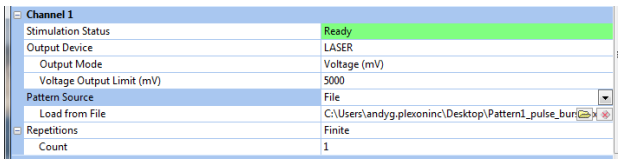
If your output mode is in mV or mA, you should not select Light Power as your file's units. Likewise, if your output mode is in mW, you should not select Voltage or current as your file's units.

After you select the units the channel is ready and the start button becomes active. A preview will appear on the left.



Hint: You can load a .txt file (with no header information) and then save it back as an .opt file including header information based on the current software settings for the selected channel by clicking on the button next to the Start All button.

The pattern stored in the file can be repeated a finite number of times or repeated continuously. This is set in the fields below Load from file. Note that if the pattern is repeated, the first value in the file will immediately follow the last value with no gap. If your pattern defines a series of pulses, you will probably want to add some zeros at the end the pattern to maintain a constant pulse "rate" during repeated playback. For this example select Continuous.



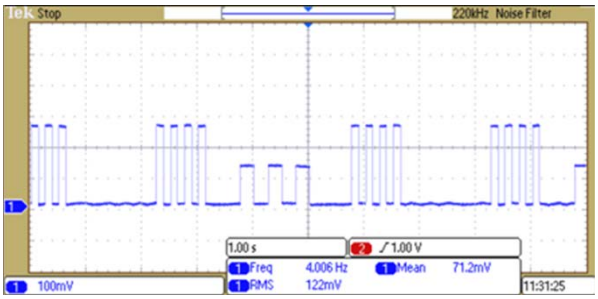
After the file has been loaded start the channel by clicking the start button at the top of the GUI.

6.8 Verifying the output on an oscilloscope

Before connecting the output to an oscilloscope, confirm that the channel is in voltage output mode. There are two ways to do this. The GUI should say Laser – Voltage and the LED on the end panel below the text that says I (on) V (off) should be off.

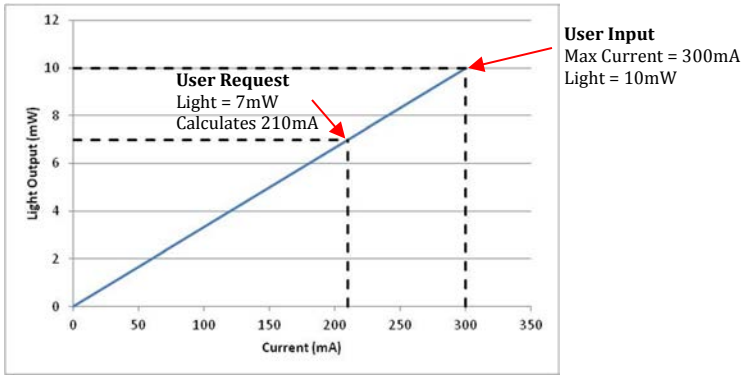
Hint: If the channel is not playing but the voltage is still ~1.25V, the channel is in current mode. In current mode, the LED is held at a voltage just below the turn-on threshold so that it can be turned on more quickly when stimulation starts.

The output for the Pattern1_pulse_bursts.txt file that was loaded in LASER – mV mode should look like the image below. Note that the scaling is 100mV per division and 1 second per division.



6.9 Using Different Scaling Options

The Optogenetic Controller fundamentally outputs either a 0-5V signal to control a laser or a 0-1100mA signal to directly power an LED. The Radiant software allows patterns to be specified in voltage or current, but some users may prefer to specify their stimulation pattern in terms of light output. By inputting the amount of light produced at the maximum current, a linear interpolation is performed. The software then calculates the amount of current or voltage required to generate any light output. As an example, if a given LED outputs 10mW of light at 300mA, this information can be used to calculate how much current is needed to output a desired amount of light of 7mW. This calculation is transparent to the user.



In order to find the light output at the max current, the entire system should be assembled (Optogenetic controller – BNC cable – LED module – Optical patch cable – Optical fiber implant).

The current is then manually set to 300mA and the light output at the end of the implant is measured with a light meter. This will compensate for any losses at each optical connection as well as any variability between LED modules. A similar calibration can be performed for lasers except that the light output will be converted to a voltage.

If LASER is the output device, selecting Power (mW) as the output mode will bring up Voltage Output Limit and Light Power fields. You need to manually enter the maximum voltage (usually 5000) and the corresponding power measured at full voltage.

If LED is the output device, the maximum current is determined by the LED Type. The user only needs to enter the measured light power at full current. If the LED Type is set to Custom, both Current Output Limit and measured Light Power at the maximum current need to be entered.

As a voltage example for lasers, put 40mW as the power at 5V. Next request 20mW of light in Manual mode and measure the actual voltage being output on an oscilloscope. You will see that it is 2.5V (5V*20mW/40mW).

7 GUI Function Reference

7.1 Status

The status of a given channel is either Not Ready or Ready. Until a pattern for a channel has been defined, the status bar will say Not Ready and the start button for that channel will be grayed out. Digital inputs to that channel will have no effect until the status changes to Ready.

7.2 Output Device

There are two choices in the drop down menu for Output Device:

1. LED
2. LASER

Whenever one of the LED choices is selected, the controller will output a current. Selecting one of the Laser modes will output a voltage. This voltage is intended to be used to control a laser with an analog control signal.

7.3 Output Mode

When the output device is set to LED, the output mode can be set to either Current (mA) or Power (mW). If Power is selected, the power delivered at the Current Output Limit must be manually entered. Note that when using one of the pre-configured Plexon LED modules, the current limit is shown next to the wavelength in the LED Type window.

When the output device is set to Laser, the output mode can be either Voltage (mV) or Power (mW). If Power is selected, the power delivered at the Voltage Output Limit must be entered.

7.4 Current or Voltage Limit

In current mode, the optogenetic controller can output more current than some LEDs can handle. To reduce the risk of damaging your LED, the current limit can be set. There are default values for Plexon's LED modules that can be selected, or a custom value can be entered. Reducing the current limit also has the additional benefit of increasing your resolution because the output is an 8 bit value ranging from 0 to the current limit. So if your limit is 1000mA, your resolution will be approximately 3.9mA. Reducing the limit to 300mA makes your resolution 1.2mA.

In voltage mode, the output can range from 0-5V. If you know that you will never need a voltage above a smaller value, you can set the voltage limit to increase the resolution.

7.5 Pattern Source

There are two options within the Pattern drop down: Manual Mode and File.

7.5.1 Manual Mode

In manual mode, a value is entered for the amplitude of a constant output. The units are mV or mA depending on if the controller is in voltage or current mode respectively.

7.5.2 File

Arbitrary waveform patterns are stimulation patterns that are defined in text files with a .opt extension. From the Pattern drop down list, select File. Then click on the folder in the File box to browse to the previously created file. When the file is opened, a graphical representation of the arbitrary waveform is displayed and the file is automatically loaded into the controller.

7.5.2.1 Creating a stimulation pattern file

The controller operates at 10kHz, meaning the stimulation output is updated every 100µs. A user-defined pattern file is simply a list of stimulation output values that are desired every 100µs. Each value is followed by a "line feed" and a "carriage return." This means that if you want to maintain the same value for a longer period of time, you must repeat the value (desired time/100µs) times. For example, stimulating 100mA for 1ms would require 10 consecutive lines of "100."

7.6 Repetitions and Count

A file based pattern can be played continuously or a finite number of time based on the setting of the Repetitions parameter. When finite Repetitions are selected, the number of repetitions may be set using the Count parameter. Note that these controls are not visible when Manual Mode is selected as the pattern source.

7.7 Trigger Options

There are three ways to initiate stimulation: Software, Edge Digital Input, and Level Digital Input. In all cases, the stimulation pattern for the channel must be defined before it can be triggered.

7.7.1 Software Triggering

Stimulation can be initiated by clicking on the Start or Start All buttons in the GUI or calling one of the start functions in the SDK. Each time Start or Start All is pressed, the stimulation pattern for the channel is initiated.

7.7.2 Digital Input Triggering

7.7.2.1 Edge Triggering

In the Edge trigger mode, stimulation begins when the Start digital input for the channel transitions from low (~0V) to high (~5V) if DI Polarity is set to Positive. If DI polarity is set to Negative, stimulation begins when the digital input transitions from high to low. The latency from digital input to stimulation onset is less than 10 µs for the first channel that is started. Since all channels are timed from the same 10 kHz clock, there is a 100µs variability when starting subsequent channels. This is because they will not start until the next 10 kHz clock edge comes following the digital input. Stopping stimulation also has a 100 µs variability because the pulse cannot end until a 10kHz clock edge is seen.

Once the stimulation pattern is triggered it will play to completion even if the Start digital input goes low during the stimulation. The pattern can be stopped by a rising edge on the Stop digital input.

7.7.2.2 Level Triggering

In the Level trigger mode, stimulation also begins when the Start digital input for the channel transitions from low (~0V) to high (~5V) when DI Polarity is set to Positive and continues until the Start digital input goes low again. The reverse is true if DI Polarity is set to Negative. The Stop digital input is not used in Level triggered mode.

7.7.2.3 DI Polarity Positive

If DI Polarity is set to Positive and the device is in Edge triggered mode, the controller responds to rising edges on the digital input start and stop pins. In Level triggered mode, the controller starts on a rising edge of the Start digital input and stops on a falling edge of the Start digital input. Note that changing polarity while a channel is loaded may cause it to start immediately depending on the current state of the digital input. If a digital input is at 0V and the polarity is changed from positive to negative, stimulation will start.

7.7.2.4 DI Polarity Negative

If DI Polarity is set to Negative and the device is in Edge triggered mode, the controller responds to falling edges on the Start and Stop digital input pins. In Level triggered mode, the controller starts on a falling edge and stops on a rising edge of the Start digital input. Note that changing polarity while a channel is loaded may cause it to start depending on the state of the digital input. If a digital input is at 5V and you polarity is changed from negative to positive, stimulation will start.

7.8 File Load Settings / File Save Settings

The settings for all channels can be saved to a user named file for future use by clicking the Save icon or by selecting Save from the File menu. These configuration files have an extension of ".ops".

The default values of the parameters can be restored by selecting File – Restore Factory Settings. You can also go to Window – Layout – Reset to Default Layout to set the windows of the GUI back to their default state.

7.9 View

When one controller is connected to the computer, there will be three choices under the View menu bar: Controller 1, Patterns 1, and Messages. Each additional controller that is connected to the computer will have an additional window for Controller and Patterns. The number corresponds to the LED number that is illuminated under "Device" on the end panel of the controller.

7.10 Window

You can adjust the appearance of the Radiant GUI in the same ways that other Plexon software packages can be adjusted. Each window can be resized, docked, undocked, or hidden completely. Once you have setup the GUI to display how you want it to, you can save the settings under Window – Layout – Save as Layout 1. You can then apply this layout if your GUI setup is changed. You can also return to the default layout at any time.

7.11 Help

The Help menu gives access to the User Manual as well as the software version number.

8 Input and Output Connectors

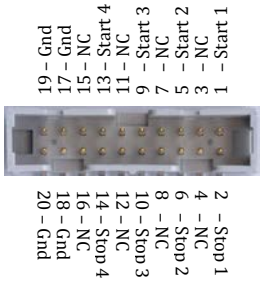
8.1 Power In

This information is provided for reference only. Use the recommended power supply and attached cable provided by Plexon to power the controller. The power input connector is a locking 2.5 mm inner / 5.5 mm outer barrel connector. The stimulator operates from a grounded 12V power supply.

Pin	Function
Center	12V
Outside	GND

8.2 Digital In

Each channel in the stimulator has a dedicated digital input (DI) that can initiate stimulation on that channel. See sections The inputs are TTL compatible.

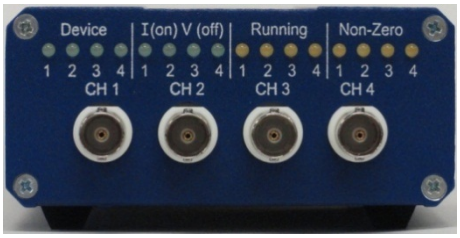


8.3 USB 2.0

The stimulator has a type B USB 2.0 receptacle for communications with the host computer. The device is not powered from the USB bus. It derives power from the power input connector.

8.4 Current or Voltage Output connectors

The stimulation output consists of four BNC connectors, one for each channel. In voltage mode, the inner contact is the output voltage and the outer contact is connected to ground. In current mode, the current going to the LED is carried on the inner contact and returns to the controller on the outer contact.



8.5 Status LEDs

There are 16 status LEDs above the output BNC connectors.

8.5.1 Device

The Device LED indicates which controller number each box is when multiple controllers are connected to a single computer. This is necessary to know which unit is being configured when multiple tabs appear in the GUI. The LED above "1" will illuminate for controller number 1, the LED above "2" will illuminate for controller number 2, etc.

8.5.2 I (on) V (off)

Each channel has a dedicated LED to indicate if it is outputting a voltage or current. If the channel is configured for current output, the LED will be illuminated. If it is configured for voltage output it will be off.

8.5.3 Running

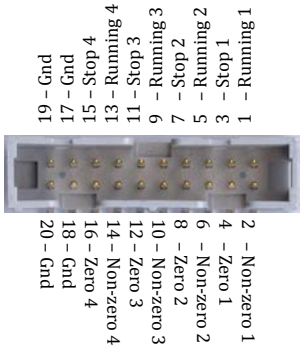
Each channel has a dedicated LED to indicate if a pattern is running. It will stay illuminated for the duration of the pattern, regardless of it the output is zero. It mirrors the output on the running digital output pin.

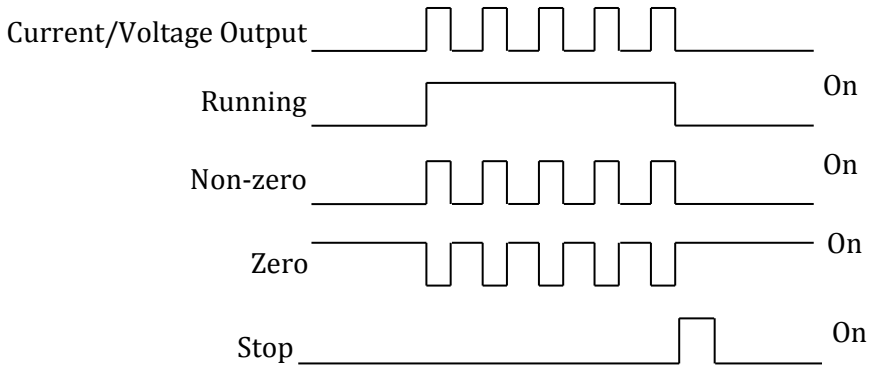
8.5.4 Non-Zero

Each channel has a dedicated LED to indicate if a pattern is non-zero. It will only be illuminated while the output is a value other than zero. So if the pattern is a series of pulses, the LED will be on during the pulse but off in between pulses. It mirrors the output on the non-zero digital output pin.

8.6 Digital Out

Each channel has four dedicated digital outputs that indicate when it is running, non-zero, zero, and when it stops. Plexon OmniPlex systems (both analog and digital) have digital input (DI) cards that allow the user to register the precise timing of stimulation. The DI cards can only be set to recognize rising or falling edges, however. This means that to fully know the timing of a pattern, multiple digital outputs of the optogenetic controller need to be monitored. The rising edge of the running signal indicates a pattern has started and the rising edge on the stop signal indicates the pattern has finished. The rising edge of the non-zero signal indicates that a pulse has started and the next rising edge of the zero signal indicates that the pulse has ended.





8.7 Stimulation Cables

While any BNC cable can be used for stimulation, Plexon provides insulated BNC cables that prevent the outer contacts from touching. This is particularly useful when using the controller in current output mode. The circuit that sets the current output relies on measuring the return current, so if the outer BNC contact were shorted to ground through accidental contact with something else (a metal table for example), the output current would not be accurate.

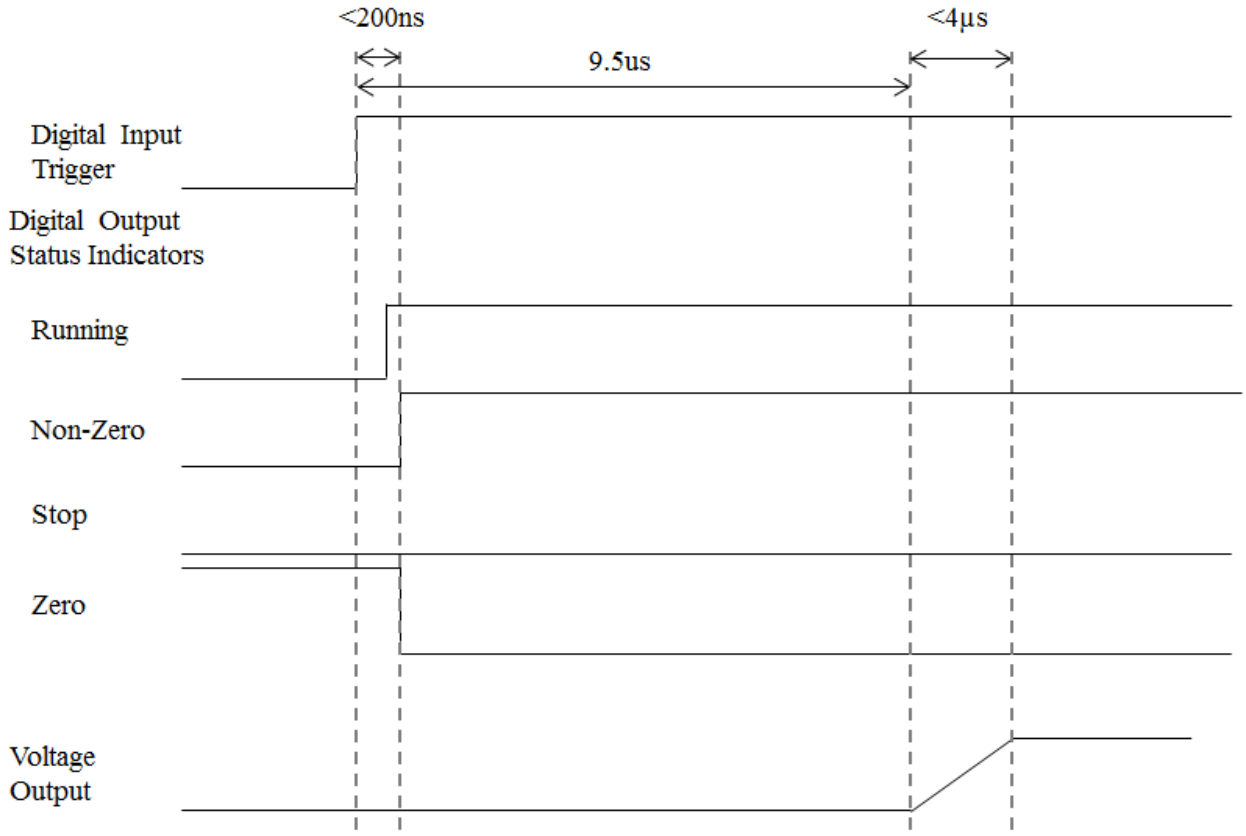
9 Sample Arbitrary Waveform Pattern Files

Several example arbitrary waveform files are installed with the Radiant software. These files were designed to illustrate how to use arbitrary waveform files and some of the things you can accomplish using arbitrary waveform files. By default these files are installed in the directory "C:\Plexon Data\Sample Pattern Files". The files can be opened with any text editor (e.g. Notepad). The sample files are marked as Read Only. They should be copied and renamed before removing the Read Only flag to avoid accidentally overwriting them.

10 Optogenetic Controller Limitations

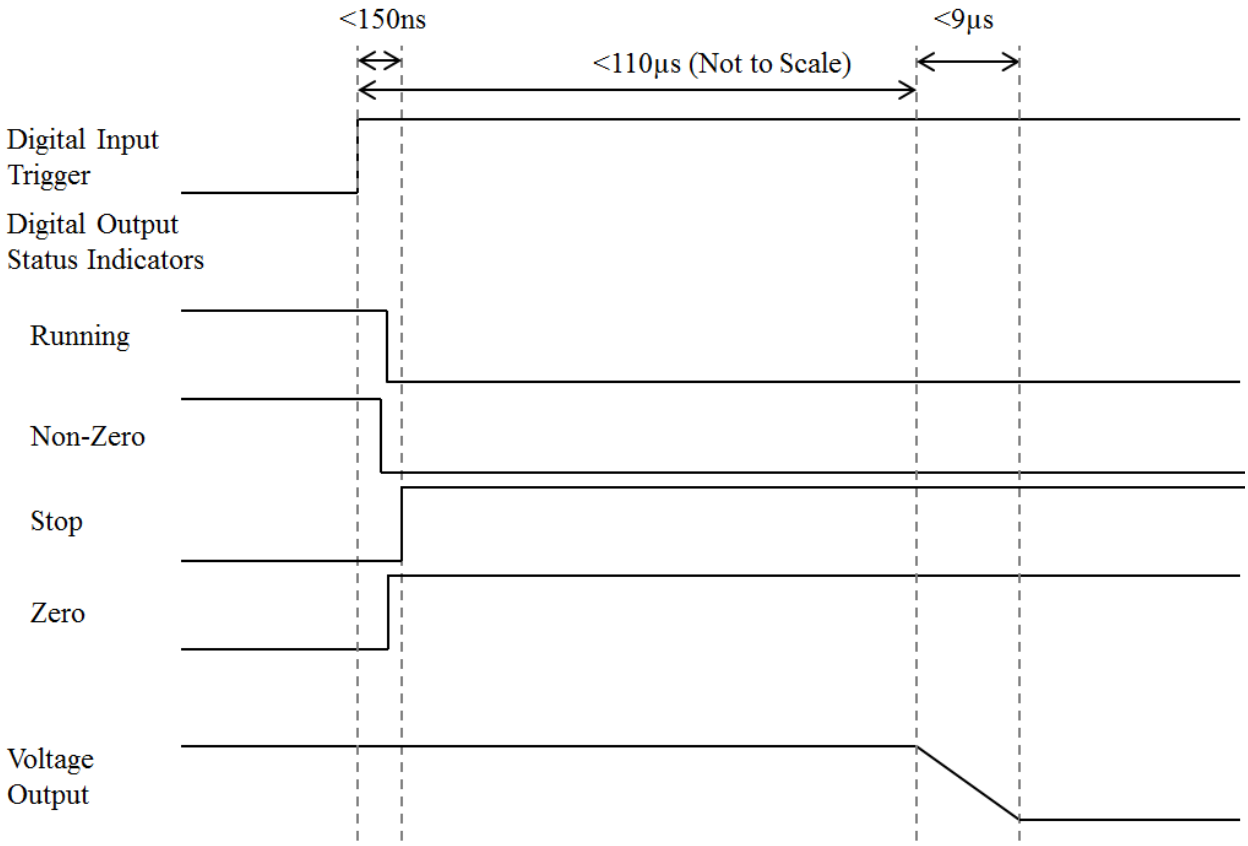
10.1 Latency between digital input and voltage output

The timing dynamics in voltage mode of starting the first channel with a digital input are shown below. All digital outputs change to reflect that a digital input trigger has been detected within 200ns, though not exactly at the same time. The voltage output begins to change 9.5us after the digital input trigger, and the rise time of the voltage output is less than 4us.



Because all channels operate on the same 10kHz clock, there is 100µs of variation in start latency when starting a second channel while the first is running. This is because the second channel cannot start until a rising edge of the 10kHz clock is seen, and this clock is asynchronous to the digital input.

Digital stop timing in voltage mode is shown below. All digital outputs change to reflect that a digital input stop trigger has been detected within 200ns, though not exactly at the same time. The voltage output begins to fall within 110us (just over one sampling period) after the digital input trigger, and the fall time of the voltage output is less than 9us.



In current mode, there are additional delays associated with the current generation circuit and the LED turning on. 300mA and 1000mA LEDs were tested at 100mA and their respective maximum currents. The worst case observed time between the digital input and the light reaching 90% of its maximum was 320µs. The rise time of the light output from 10% to 90% was up to 180µs, and the fall time was up to 300µs. In general, rise times were actually shorter for higher currents. Additionally, orange modules had shorter rise times than blue modules. Fall times were approximately the same across different the current values for a given module. The blue modules had longer fall times than orange ones. These delays are still small relative to the kinetics of the opsins that are available at this time.

10.2 Synchronization of multiple Controllers

The Radiant GUI supports connecting up to four controllers to a single computer. It should be noted that each controller has its own internal clock and this will result in slight timing variations between Controllers. This variation will be most noticeable during very long stimulation protocols.

The crystal that generates the clock has 50 ppm stability. In the worst case, if your pattern is an hour long, it could potentially finish 0.36 seconds earlier or later than the same pattern running on a second controller that was started at the same time (assuming one clock is 50 ppm fast and one is 50 ppm slow). This is a worst-case scenario, but there will certainly be some drift between different controllers.

If you have a long pattern that actually consists of smaller repeated pattern, the best option is to define a pattern consisting of just one basic unit and then use a digital input to trigger all of the controllers at the same time. As an example, rather than repeating a 1 second pattern 3600 times in software or a file, you could define the 1 second pattern, set the number of repetitions to 1, and trigger all of the controllers with the same 1Hz digital input. This will prevent drift between Controllers.

10.3 LED Flashes when changing from voltage to current mode

If an LED is connected to the controller while it is in voltage mode and the output is switched to current mode, a brief pulse of light approximately 4ms long will occur as the current output stabilizes at zero. The current generation circuit is designed to hold the voltage applied to the LED just below the turn on threshold so that light can be generated as quickly as possible in response to a start command. When the controller is in voltage mode, the current generating circuit is disconnected from the LED. This prevents it from setting its output at this threshold value. When it is switched to current output, there is a brief stabilizing period lasting approximately 4ms. The easiest way to avoid this is to switch to current mode before connecting the LED to the controller or before connecting the patch cable to the LED module.

11 Specifications

General		
Dimensions	power supply controller	5.8 in x 1.3 in x 2.4 in 8.0 in x 1.9 in x 3.8 in
Weight	power supply stimulator	1.0 lbs 1.2 lbs
Power requirements		100 – 240 VAC, 47 – 63 Hz, 0.96 – 0.51 A
Operating Systems		Windows XP, Windows 7
Interface		USB 2.0
Analog outputs		
Stimulation mode		Voltage or Current
Number of analog output channels		4
Maximum Current (Current Mode)		1100 mA
Maximum Voltage (Voltage Mode)		5V
Resolution for setting Max Current or Voltage		4.3mA, 19.5mV
Output Resolution		(Max current or voltage)/256
Output accuracy with max set to 5V		for outputs <= 800 mV, error less than ±10 mV for outputs > 800 mV, error less than ±1%
Output accuracy with max set to 1000mA		±2 SD: -3.9mA / +4.0mA
Temporal resolution		100 µs
Output rise time (Voltage Mode)		<4 µs 0-5V, 1 MΩ, 11.5 pF load
Minimum LED light pulse width		500 µs (amplitude dependent)
Digital inputs/outputs		
Number of digital inputs		8 (2 per channel)
Number of digital outputs		16 (4 per channel)
Digital input levels		TTL, Low < 0.8V, High > 2.0V
Digital output levels		HCT, Low < 0.33V, High > 3.84V
Digital input/output latency		See section
Minimum trigger pulse width		200 ns
Arbitrary waveforms		
Update rate		10 kHz

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Optogenetic Controller December 2012