1 Overview

This document provides specifications for a *firefly simulator*. This device is intended to simulate the light displays of common fireflies, such as *Photinus pyralis*. The *firefly simulator* will provide means to control the brightness, duration, and other relevant parameters of the simulated light display. Light-emitting diodes (LEDs) will be used as the light source, and the color of the display can be altered by connecting different LED types to the simulator.

The *firefly simulator* can be configured via commands issued to it from a host computer, as shown in Fig. 1. The physical link between the host computer and the *firefly simulator* is an asynchronous serial communications interface, which can be accomplished with a common and inexpensive USB adapter. The *firefly simulator* also can return status information to the host computer via the same interface.

Once configured, the *firefly simulator* can be used in a stand-alone mode, without requiring a connection to a host computer. Pushbuttons on the *firefly simulator* can be used to activate light displays that were previously configured. When in the stand-alone mode, the simulator can be powered by a USB powerbank.

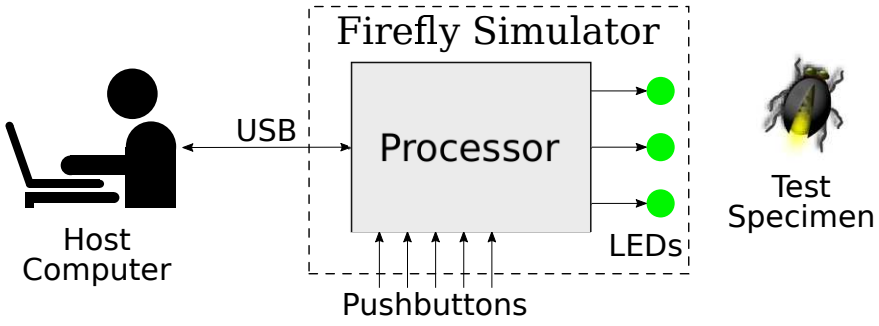

Figure 1: Firefly Simulator Block Diagram

This document describes the minimum required functionality of the *firefly simulator*. Possible future enhancements to the simulator include:

- The ability to sense the behavior of a test specimen and use that behavior to modify the parameters of a light display.
- The ability to record information about simulator activity on non-volatile memory, such as a removable Secure Digital (SD) memory card.
- The addition of a real-time clock (RTC) to the *firefly simulator* so that timestamps can be added to response messages from the simulator to the host computer.

2 References

IEEE Standard for Transitions, Pulses, and Related Waveforms, IEEE Standard 181, 2011.

3 Definitions

ASCII	The American Standard Code for Information Interchange. The letters in the English alphabet, the decimal digits, and common punctuation marks are assigned a unique 7-bit binary code.
blink	The process of bringing the *illumination level* of an *LED* from 0% to 100% then back to 0% illumination. A *blink* consists of a *ramp up*, followed by an *on time*, followed by a *ramp down*. A *blink* begins at t_1 and ends at t_4, as shown in Fig. 2. The interval from t_1 to t_2 is the *ramp up*. The interval from t_2 to t_3 is the *on time*. The interval from t_3 to t_4 is the *ramp down*.

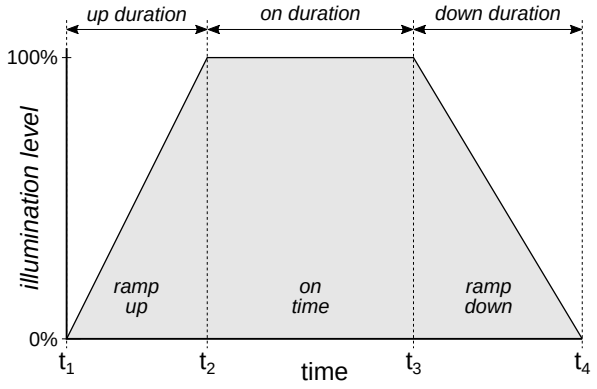

Figure 2: *blink* waveform

channel — The *channel* of an *LED* is an integer that specifies which physical output connector of the firefly simulator is connected to the physical LED. The value of *channel* is an integer and shall not be less than 1 and not greater than *max channel*.

Note that the *channel* is not the pin number of any particular microcontroller. An implementation of the firefly simulator must perform the appropriate mapping of an *LED*'s *channel* to an appropriate physical pin on the output device.

down duration — The length of the *ramp down* interval. The *down duration* is equal to $t_4 - t_3$, as shown in Fig. 2. The *down duration* shall be a non-negative integer value with units of milliseconds. The value of *down duration* shall not be less than 0 or greater than 32 767.

illumination level — The brightness of an *LED* at any given point in time, as a percentage of that *LED*'s *max brightness*. The *illumination level* and *max brightness* values indirectly translate to the average current passing through the physical LED.

At any given point in time, the average current for an LED is

$$I_{AVG} = \frac{illumination\,level}{100} \times \frac{max\,brightness}{100} \times I_{max}$$

message — A sequence of *message fields*, separated by the ASCII comma character (decimal 44) and terminated by either the ASCII Line Feed (decimal 10), the ASCII Carriage Return (decimal 13), or both the Line Feed and the Carriage Return. There shall not be a comma before the first field in a message nor after the last field.

message field — A sequence of one or more ASCII characters from the set of uppercase letters (`A` through `Z`) and decimal digits (`0` through `9`). A message field shall not include any characters or values other than the uppercase letters and decimal digits.

max brightness — The maximum duty factor of the *pulse-width modulation* signal that controls the *illumination level* of an *LED*. The *max brightness* is a characteristic of an *LED*. The value of *max brightness* is an integer and shall be not less than 1 and not greater than 100.

max channel — The number of physical *LED channels* available on a particular implementation of a *firefly simulator*. The value of *max channel* shall not be less than 1 or greater than 127 for any implementation of a *firefly simulator*.

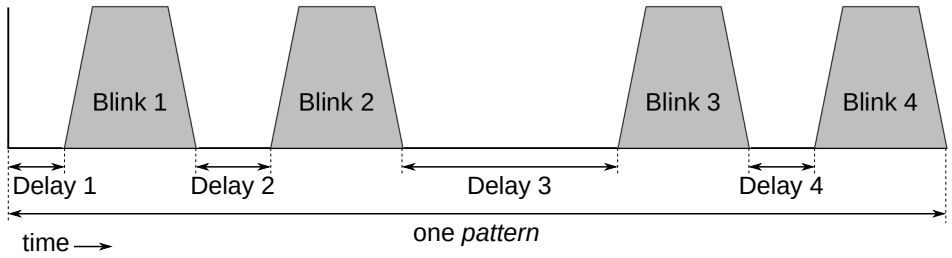

Figure 3: *pattern* timeline (without a *wait event*)

max blink	The number of unique *blink* configurations available on a particular implementation of a *firefly simulator*. The value of *max blink* shall not be less than 1 or greater than 127 for any implementation of a *firefly simulator*.
max pattern	The number of unique *pattern* configurations available on a particular implementation of a *firefly simulator*. The value of *max pattern* shall not be less than 1 or greater than 127 for any implementation of a *firefly simulator*.
on duration	The length of the *on time* interval. The *on duration* is equal to $t_3 - t_2$, as shown in Fig. 2. The value of *on duration* shall be a positive, non-zero integer with units of milliseconds. The value of *on duration* shall not be less than 1 or greater than 32 767.
on time	The period of time during a *blink* when the *LED* is constantly at an illumination level of 100%.
pattern	A sequence of up to four *blinks* with user-specified delays before each *blink*, as shown in Fig. 3.
ramp down	The process of linearly decreasing the *illumination level* of an *LED* from 100% to 0%.
ramp up	The process of linearly increasing the *illumination level* of an *LED* from 0% to 100%.
up duration	The length of the *ramp up* interval. The *up duration* is equal to $t_2 - t_1$, as shown in Fig. 2. The value of *up duration* shall be a non-negative integer with units of milliseconds. The value of *up duration* shall not be less than 0 or greater than 32 767.

4 Resolution and Accuracy

4.1 Brightness

The *firefly simulator* does not directly control the brightness of a physical LED. Instead, the simulator controls the average current provided to the LED. The simulator's configuration messages allow the actual average current (I_{AVG}) of an LED to be specified with a resolution of $\pm 1\%$ of the maximum available current (I_{MAX}). The maximum available current, and the precision which with the current can be specified, will be determined by the circuitry associated with a given physical LED and need not be the same for all LEDs.

4.2 Time

Values that represent time shall have units of milliseconds and a resolution of 1 ms. The accuracy of all pulse durations and time delays generated by the *firefly simulator* shall have a maximum error of ± 10 ms.

5 Configuration Messages

The firefly simulator is configured via a serial communications interface to a host computer. The host computer can set the values of all parameters for *LEDs*, *blinks*, and *patterns*. A unique configuration message format is specified for configuring an *LED*, configuring a *blink*, or configuring a *pattern*.

5.1 *capacity query/capacity response messages*

The *capacity query message* can be used by the host computer to determine the capabilities of a *firefly simulator*.

Table 1: Definition of *capacity query message*

Field Number	Field Name	Description	Format
1	Header	Unique first character for an *capacity query message*	This field shall be the uppercase letter '`C`'.

The *firefly simulator* will respond to the *capacity query message* by sending a *capacity response message* to the host computer.

Table 2: Definition of *capacity response message*

Field Number	Field Name	Description	Format
1	*max channel*	The number of physical LEDs available	This field shall contain a decimal integer from 1 to 127.
2	*max blink*	The number of available *blink* definitions	This field shall contain a decimal integer from 1 to 127.
3	*max pattern*	The number of available *pattern* definitions	This field shall contain a decimal integer from 1 to 127.

5.2 *LED configuration message*

An *LED configuration message* is sent from the host computer to the firefly simulator. Every *LED configuration message* shall contain three *message fields*, as shown in Table 3.

Table 3: Definition of *LED configuration message*

Field Number	Field Name	Description	Format
1	Header	Unique first character for an *LED configuration message*	This field shall be the uppercase letter '`L`'.
2	LED *channel*	A unique identifier for each physical LED	This field shall contain a decimal integer from 1 to *max channel*.
3	*max brightness*	The maximum brightness level for the LED	This field shall contain a decimal integer from 1 to 100.

5.3 *blink configuration message*

An *blink configuration message* is sent from the host computer to the firefly simulator. This message provides the parameters for a single *blink* of an *LED*, as shown in Table 4.

Table 4: Definition of a *blink configuration message*

Field Number	Field Name	Description	Format
1	Header	Unique first character for a *blink configuration message*	This field shall be the uppercase letter '`B`'.
2	*blink* number	A unique identifier for each *blink* definition	This field shall contain a decimal integer from 1 to *max blink*.
3	LED number	Identifier for the *LED* to be illuminated in this *blink*	This field shall contain a decimal integer from 1 to *max channel*.
4	*up duration*	The duration of the *ramp up* in milliseconds	This field shall contain a decimal integer from 0 to 32 767.
5	*on duration*	The duration of the *on time* in milliseconds	This field shall contain a decimal integer from 1 to 32 767.
6	*down duration*	The duration of the *ramp down* in milliseconds	This field shall contain a decimal integer from 0 to 32 767.

5.4 *pattern configuration message*

An *pattern configuration message* is sent from the host computer to the firefly simulator. This message provides the parameters for a single *pattern* of one or more *blinks*, as shown in Table 5. Note that the same *blink* may be repeated within a pattern or up to four different *blinks* may be combined.

Table 5: Definition of a *pattern configuration message*

Field Number	Field Name	Description	Format
1	Header	Unique first character for a *pattern configuration message*	This field shall be the uppercase letter '`P`'.
2	*pattern* number	A unique identifier for each *pattern* definition	This field shall be a decimal integer from 1 to *max pattern*.
3	Delay 1	The duration of the delay from the beginning of the pattern to the first *blink*, in milliseconds	This field shall contain a decimal integer from 0 to 32767.
4	Blink 1	The identifier of the first *blink* in the pattern	This field shall contain a decimal integer from 0 to *max blink*. A value of 0 causes this blink to be omitted from the pattern.
5	Delay 2	The duration of the delay from the end of the first *blink* to the beginning of the second *blink*, in milliseconds	This field shall contain a decimal integer from 0 to 32767.
6	Blink 2	The identifier of the second *blink* in the pattern	This field shall contain a decimal integer from 0 to *max blink*. A value of 0 causes this blink to be omitted from the pattern.
7	Wait 1	The identifier of a *wait event*	This field shall be a single decimal digit from '0' to '9'. A value of '0' indicates that there is no *wait event*.
8	Delay 3	The duration of the delay inserted before the beginning of the third *blink*, in milliseconds	This field shall contain a decimal integer from 0 to 32767.
9	Blink 3	The identifier of the third *blink* in the pattern	This field shall contain a decimal integer from 0 to *max blink*. A value of 0 causes this blink to be omitted from the pattern.
10	Delay 3	The duration of the delay from the end of the third *blink* to the beginning of the fourth *blink*, in milliseconds	This field shall contain a decimal integer from 0 to 32767.
11	Blink 4	The identifier of the fourth *blink* in the pattern	This field shall contain a decimal integer from 0 to *max blink*. A value of 0 causes this blink to be omitted from the pattern.

6 Command Messages

The host computer can command the *firefly simulator* to turn on an *LED* at a specified *illumination level*, execute a specific *blink*, execute a specific *pattern*, or execute all available *patterns* in a pseudorandom order.

6.1 *Execute LED message*

An *Execute LED message* is sent from the host computer to the firefly simulator. This message can be used to turn an LED on or off for testing or calibration purposes. Every *Execute LED message* shall contain three *message fields*, as shown in Table 6.

Table 6: Definition of *Execute LED message*

Field Number	Field Name	Description	Format
1	Header	Unique first two characters for an *Execute LED message*	This field shall be the uppercase letters '`XL`'.
2	LED *channel*	A unique identifier for a physical LED	This field shall contain a decimal integer from 1 to *max channel*.
3	*illumination level*	Sets a constant value for the *illumination level* of the *LED*	This field shall contain a decimal integer from 0 to 100. A value of 100 causes the *illumination level* of the LED to be set at a constant value of 100% (of the *LED*'s *max brightness* level). A '0' shall cause the *illumination level* of the LED to be set at 0% (completely dark).

6.2 *Execute blink message*

An *Execute blink message* is sent from the host computer to the firefly simulator. This message can be used to cause the firefly simulator to repeatedly execute a specific *blink* sequence. Every *Execute blink message* shall contain three *message fields*, as shown in Table 7.

This command can be terminated before the simulator reaches the specified repeat count by **TBD**.

Table 7: Definition of *Execute blink message*

Field Number	Field Name	Description	Format
1	Header	Unique first two characters for an *Execute blink message*	This field shall be the uppercase letters '`XB`'.
2	*blink* number	A unique identifier for a *blink*	This field shall contain a decimal integer from 1 to *max blink*.
3	Repeat	A positive, non-zero integer value specifying the number of times that the *blink* should be repeated.	This field shall a decimal integer from 1 to 32 767.

6.3 *Execute pattern message*

An *Execute pattern message* is sent from the host computer to the firefly simulator. This message can be used to cause the firefly simulator to repeatedly execute a specific *pattern*. Every *Execute pattern message* shall contain

three *message fields*, as shown in Table 8.

This command can be terminated before the simulator reaches the specified repeat count by **TBD**.

Table 8: Definition of *Execute pattern message*

Field Number	Field Name	Description	Format
1	Header	Unique first two characters for an *Execute pattern message*	This field shall be the uppercase letters '`XP`'.
2	*pattern* number	A unique identifier for a *pattern*	This field shall contain a decimal integer from 1 to *max pattern*.
3	Repeat	A positive, non-zero integer value specifying the number of times that the *pattern* should be repeated.	This field shall a decimal integer from 1 to 32 767.

6.4 *Execute random pattern message*

An *Execute random pattern message* is sent from the host computer to the *firefly simulator*. This message can be used to cause the simulator to pseudo-randomly select and execute patterns from the set of all configured patterns. The simulator will continuously execute patterns until **TBD**.

Table 9: Definition of *Execute random pattern message*

Field Number	Field Name	Description	Format
1	Header	Unique first two characters for an *Execute random pattern message*	This field shall be the uppercase letters '`XR`'.