Aphos 32 Operating Manual

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1 Overview of the Aphos 32 Strobe light

The Aphos 32 Strobe light (strobe) is a pulsed only high intensity LED light designed for subsea operation. It consists of a subsea bottle and an LED panel. The bottle contains the control and interface electronics along with the energy storage capacitor banks and charging circuits. For reliability, the strobe consists of four independent channels each with their own charging, monitoring and storage circuits.

Fig.1 Photo of the Aphos 32 Strobe light

The LED panel consists of 4 channels each with 8 high Power LED's connected in series. Each channel is routed back to its associated channel in the bottle. The LED panels come in wide angle and controlled angle variants. To trigger the light, a TTL level trigger is applied to the Trigger +/- inputs via the rear bulkhead connector. The trigger input circuit is optically isolated. The light uses its own internal timing register to determine how long to fire for. This register is controllable over the RS485 interface.

To aid in quick deployment of the light, each Aphos 32 is programmed to automatically charge on power up. This means that the light can be strobed by applying a trigger signal, there is no software control required. Table 2 details the lights default factory setup. The light can be further controlled and configured via the RS485 interface on pins 3 and 4 of the rear bulkhead connector. The Strobe light has a full set of control registers and details

of these are provided in the Serial communications section. The internal microcontroller in the light is equipped with a data EEPROM so the light will retain any settings that are programmed into its registers over the serial interface.

2 Serial Communications Setup

The light is equipped with an RS485 half-duplex serial interface. The baud rate used to communicate with the lights is 57600 baud. It is possible to change the baud rate to one of a fixed number of speeds. The data format used is 8 data bits, no parity and 1 stop bit (8N1). Fig.4 shows a screen shot from the Putty terminal software showing an example of the serial setup for COM6

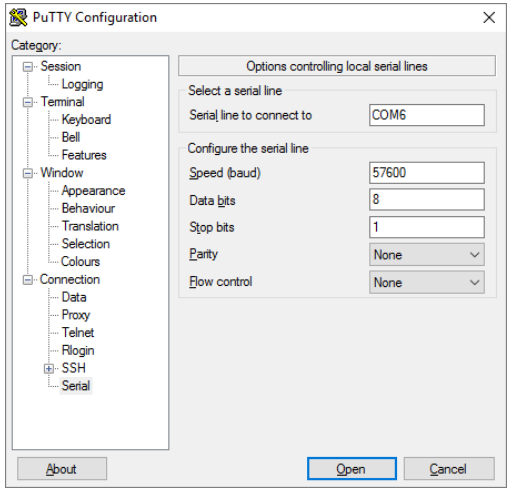

Fig.4 Serial setup for the Aphos 32 CLI

The communications architecture is a master/slave system in the light. The light will never send data onto the RS485 bus unless it is asked to do so by the host.

2.1 Packet structure Host to Aphos

Fig.5 illustrates the packet structure for querying or commanding the light.

1	2	3	4	5	6	7	8	9	10	11	12
<	C	,	Address	,	Register	,	Value 1	Value 2	*	Checksum	>

Fig.5 Host to Aphos Strobe packet structure

When sending a query or command to a light the packet fields are broken down as shown in table 4;

Field	Value	Description
1	"<"	Packet start delimiter
2	"C"	Command or Query from Host to light.
3	","	comma - internal field delimiter
4	"address"	Number from 1 to 255. This is the address of the light on the wire
5	","	comma - internal field delimiter
6	"register"	Register you want to access
7	","	comma - internal field delimiter
8	"value 1"	Command specific value (LED Channel identifier)
9	"value 2"	Command specific value
10	"*"	Internal field delimiter to indicate that the following field is a checksum
11	"Checksum"	The checksum can be calculated at the host and sent down. It is a 16 number. Alternatively, by sending "ZZZZ" in place of the checksum, the command will still be executed by the light.
12	">"	Packet end delimiter

Table 4. Host to Aphos 32 packet format

2.1.0.1 Note 1:

Field 9 is optional. Many commands will have only a single parameter. Also when reading data from the light, you do not send anything in Field 8 or 9. The light will interpret the lack of parameters as a 'Get' command and return the relevant data to the Host. If a parameter is present in Field 8 (9) then the light will interpret this command as a 'Set' command.

2.1.0.2 Note 2:

For Strobe firmware version 132 and earlier, you need to append a carriage return and line feed (CRLF) onto the end of each packet sent to the light as there is a bug in the lights CLI code that causes intermittent packet receive failures. This has been resolved in later firmware versions. Fig.6 below illustrates how this can be appended in the Putty terminal program.

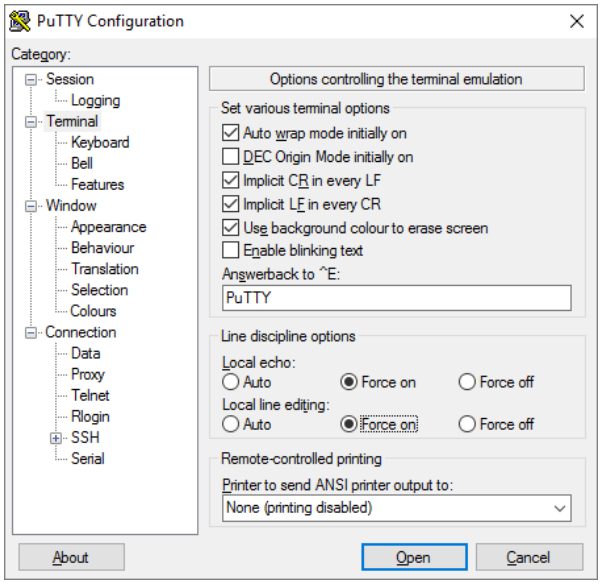

Fig.6 Putty setup to append CRLF onto each packet sent to the lights

2.2 Packet structure Aphos to Host

Fig.6 below illustrates the packet structure used by the light when responding to the host. The packet below is a single character response packet. In this case field 6 is the value returned from the light. Some queries from the light will result in more than one character being returned.

1	2	3	4	5	6	7	8	9
<	R	,	Address	,	value	*	Checksum	>

Fig.6 Aphos Strobe to Host packet structure

Field	Value	Description
1	"<"	Packet start delimiter
2	"R"	Response from Host to light.
3	","	comma - internal field delimiter
4	"address"	Number from 1 to 255. This is the address of the light on the wire
5	","	comma - internal field delimiter
6	"register"	Register you want to access
7	","	comma - internal field delimiter
8	"value 1"	Command specific value
9	"*"	Internal field delimiter to indicate that the following field is a checksum
10	"Checksum"	The Aphos will always return a checksum
11	">"	Packet end delimiter

Table 5. Aphos to Host packet structure

2.3 Basic light operations

When the light leaves the factory it is setup in a ready to operate configuration. The light will simply need power and a valid trigger to begin firing. There is no requirement to control the light via the RS485 interface unless you wish to adjust its parameters.

The light is relatively simple to control and for most operations the only parameters that will need adjustment are the pulse duration and the light intensity.

2.3.1 Adjusting the pulse duration

The commands below can be used change the length of time that the light will turn on for when a trigger is received. The command is detailed in Table 6. Refer to the Command reference section for a list of all commands, their format and the expected reply.

Command (Host to Aphos)	Response (Aphos to Host)	Details
<C,2,s_pulse 3000*ZZZZ>	None	This sets the pulse duration to 3000 usec
<C,2,s_pulse*ZZZZ>	<R,2,3000*ZZZZ>	This command asks the light to send back its pulse duration

Table 6 setting the light pulse duration

2.3.2 Adjusting the LED intensity

The LED intensity will increase or decrease the LED power emitted from the panel. Be aware that the amount intensity of the panel will diminish as the frame rate increases. This is due to the fact that at high frame rates there is less time available for the capacitor banks to charge.

Command (Host to Aphos)	Response (Aphos to Host)	Details
<C,2,c_level 0 84*ZZZZ>	None	This sets the LED intensity to 84%

Table 7 setting the LED intensity level

2.4 Command reference

The following commands can be used to communicate with the lights. For this table the lights RS485 address is assumed to be 2.

Command	Syntax (Host to A32)	Syntax (A32 to Host)	Details
s_mode	<C,2,s_mode 1*ZZZZ>	None	This command will program the light into single shot mode. This is a non-volatile command
	<C,2,s_mode 0*ZZZZ>	None	This command will program the light for normal pulsed operation. This is a non-volatile command
	<C,2,s_mode*ZZZZ>	<R,2,**1***ZZZZ>	By not sending a parameter the light will respond with the current s_mode value. In this case, s_mode is set to 1, i.e. single shot mode. (**Note Checksum set to 'ZZZZ' for read examples**)
s_shot	<C,2,s_shot 65*ZZZZ>	None	This command sets the single shot pulse duration. The units are msec, and the range is from 1msec to 100msec. In this example the shot duration is set to 65msec
	<C,2,s_shot*ZZZZ>	<R,2,**65***ZZZZ>	This command reads the single shot pulse duration from a light. In this case the value is 65 so the light will fire for 65msec once a trigger is detected
s_trigger	<C,2,s_trigger 1*ZZZZ>	None	This command sets the light to be falling edge triggered. (**W.R.T the trigger signal at the bulkhead**)
	<C,2,s_trigger 0*ZZZZ>	None	This command sets the light to be rising edge triggered
	<C,2,s_trigger*ZZZZ>	<R,2,**0***ZZZZ>	This command reads the lights trigger edge configuration. In this case the light it **rising** edge triggered.
set_vcap	<C,2,set_vcap 53*ZZZZ>	None	This command sets the charge voltage on the capacitor banks. The units are volts and must be entered as integers. The range is from 10V to 56V. For single shot operating, 53V is recommended.
	<C,2,set_vcap*ZZZZ>	<R,2,**53***ZZZZ>	This command reads the lights capacitor bank target voltage. In this case the lights will charge the capacitors to 53V
	<C,2,auto_en 2*ZZZZ>	None	This command sets the light to auto charge on power up. When it is sent to the light it is effective from the next restart.
	<C,2,auto_en 0*ZZZZ>	None	This command sets the light so that capacitor charging only occurs when a charge_en command is

auto_en			received. When it is sent to the light it is effective from the next restart.
	<C,2,auto_en*ZZZZ>	<R,2,**2***ZZZZ>	This command reads the auto charge register. In this case the light is set to auto charge on power up.
Command	**Syntax (Host to A32)**	**Syntax (A32 to Host)**	**Details**
c_level	<C,2,c_level 0 80*ZZZZ>	None	Set the light level to 80%. Range is 0 to 100.
s_delay	<C,2,s_delay 100*ZZZZ>	None	Set light to wait 100usec after trigger is detected to power on the LED's
	<C,2,s_delay*ZZZZ>	<R,2,**100*** ZZZZ >	Light response, strobe delay is 100usec
s_pulse	<C,2,s_pulse 2500*ZZZZ>	None	Set strobe LED pulse duration to 2500usec for pulsed mode operation
	<C,2,s_pulse*ZZZZ>	<R,2,**2500*** ZZZZ >	Light response, strobe duration is 2500usec
version	<C,2,version*ZZZZ>	<R,2,**132***ZZZZ>	This command allows you to read the firmware version from the light
s_no	<C,2,s_no*ZZZZ>	<R,2,**199***ZZZZ>	This command will read the lights serial number which should match the numerals stamped on the lights base plate. In this example the lights serial number is A32-0199
d_address	<C,2,d_address 3*ZZZZ>	None	This command can be used to change a light's RS485 address; in this case the lights address is changing from 2 to 3. The usable range is 0 – 254. Address 255 is reserved as a broadcast address.
	<C,2,d_address*ZZZZ>	<R,2,**2***ZZZZ>	In this case the light responds with its RS485 address.
	<C,255,d_address 2*ZZZZ>	None	Using the command in this manner will change the RS485 address of any light on the network from whatever it is to 2. So if you have a light with an unknown RS485 address you can use this command to set it to a known value.

3 Aphos 32 architecture

3.1 Capacitor bank charging

The Aphos 32 has been designed to operate with low input power, using a slow charge /rapid discharge architecture. The purpose of this is to ensure that the strobe light takes very little power from the vehicle power supply when the light pulse is active.

Figure 2 below shows a graph of data gathered from an Aphos 32 operating with a 24VDC supply and triggered by a 4Hz source. The light was setup to generate 3.5msec lights pulses at maximum output power. The blue trace is the power taken by the light during the charging cycles, the orange trace is the LED power for Channel 1 of the Aphos 32. The graph shows the power required by the light drops when the light is firing so that the vehicle supply is not adversely affected by the light discharge.

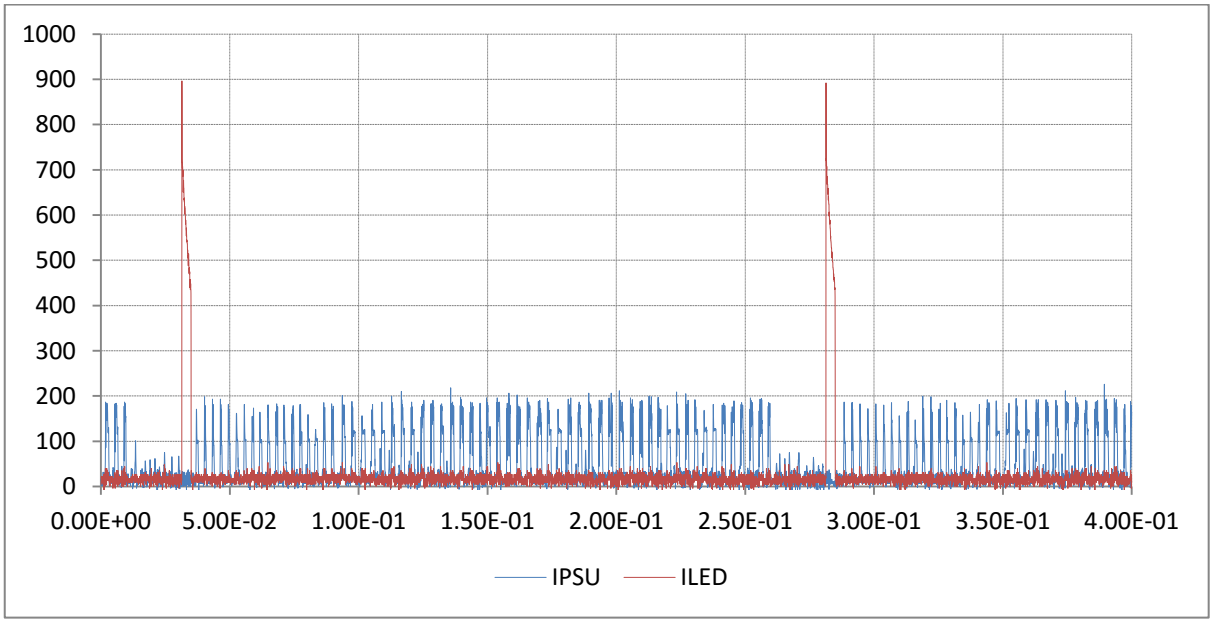

Fig.2 Power data from an Aphos 32 @4Hz

3.2 Triggering the Aphos 32

As stated above, the strobe light is configured to Auto charge by default. This means that as soon as power is applied to the Strobe light, it will begin charging. The initial (cold) charge time will vary slightly from unit to unit, but will be complete within one minute from power on. The purpose of the auto-charge control is to allow a user to operate the light without having to configure it via the RS485 interface. It is possible to change the lights setup so that it does not auto charge.

Once the cold charge is complete the light is then ready to operate. If at this point a trigger signal is present at the lights trigger + / - pin's then the light will begin to strobe.

The light will continue to strobe so long as a trigger signal is detected on the lights trigger in pins. The Strobe can operate at frame rates up to 30Hz – but be aware that the light output will diminish with increasing frame rate. Table 1 below provides as guideline on the input range of the trigger signal that can be applied to the light.

Aphos 32 Strobe Input Trigger electrical specifications			
Trigger +/- input voltage level	Minimum	Typical	Maximum
	3.0VDC	5.0VDC	12VDC
Trigger input frequency[1]	Minimum	Typical	Maximum
	1/10Hz	5Hz	30Hz
Trigger signal pulse duration[2]	Minimum	Typical	Maximum
	200usec	1msec	---
Trigger mode	Rising / Falling Edge	Software configurable	

Table 1 Aphos Strobe 32 Trigger input specifics

[1] *The frequency of operation will be a factor in determining the amount of light than the strobe can produce. Higher frequencies afford shorter recharge times for the capacitor banks*

[2] *The Strobe light is edge triggered, and can be triggered by an active high or active low signal. Also, note that the trigger input circuit is optically isolated and inverts the incoming TTL signal as it is processed. The 200usec time is defined as a safe tested minimum. Operation with smaller trigger widths is possible but has not been tested.*

4 Modes of operation

The Aphos 32 has two distinct modes of operation available, these are; Pulsed mode and Single shot mode. These modes are selectable via the RS485 CLI.

4.1.3 Pulsed Mode

Pulsed pulse mode is the default mode of operation, in this mode the light will emit a pulse of light for every input trigger it receives. This is the normal operational mode of the light and would be the typical mode of operation for the light.

4.1.4 Single Shot Mode

Single shot mode is a secondary mode of operation designed for use in stationary undersea systems that would not be taking images sequentially. This mode of operation allow for very long light pulses to be generated in the light (up to 200msec), but the pulse repetition rate is much lower than in Pulsed mode, approx 1 image every 10 seconds.

The Aphos 32 ships in Pulsed pulse mode as default unless specified. The lights mode can be changed via the serial interface and the mode is a saved setting in the lights Eeprom.

4.2 Factory settings

The strobe light is factory configured with some default operational settings. For the most part the factory settings can be used as good defaults throughout the products life. However there are some parameters that may require tuning depending on the application. Table 2 details the factory default register load out.

Aphos 32 Strobe Default Operational Settings				
LED pulse duration	Minimum	Typical	Maximum	Factory set
	200µsec		10000µsec[1]	2500µsec
RS485 Address	Minimum	Typical	Maximum	Factory set
	1		254	2[2]
Automatic charge	Enabled	Disabled		Factory Set
	1 or 2	0		2
LED current limit	Minimum	Typical	Maximum	Factory set
	1000mA	25000mA	27000mA	25000mA[3]

Table 2 Snapshot of factory set registers

[1] *The LED pulse duration is the time that the LED's are on once the pulse has been detected. The larger this number is the longer the LED pulse is, and consequently the larger the power demand from the capacitor banks.*

[2] *The RS485 address will be set to 2 if the light is shipping in a quantity of 1. If however there is more than one light in the order, then the serial number of the light will determine the RS485 address.*

[3] *The LED target current is used by the Lights PID control algorithm to set and maintain the peak current output from the light. As with point [1] a large figure here will require more power than a smaller figure. To achieve an output of 100000 Lumen at 5Hz, it is recommended to put this number to 18000.*

4.3 Strobe operation – Pulsed

The strobe light contains an internal microcontroller that controls how the capacitor banks are charged and also monitors the LED channel current to maintain output stability over a range of trigger frequencies and pulse durations.

When pulsing the Strobe light is effectively a finite state machine. Note here that during the pulse, the light electrically disconnects itself from the vehicles power system to prevent the vehicle 'seeing' a spike in power demand during the pulse duration. Table 3 shows how the light changes state when strobing.

1→	2→LED ON	3→ LED OFF	4→ LED OFF	5→ LED OFF	6→ LED OFF	7→ LED OFF
DELAY	**PULSE (LED ON)**	**CHARGE 1**	**CHARGE 2**	**CHARGE 3**	**CHARGE 4**	**TRICKLE**
CH1 OFF	**CH1 LED ON**	**CH1 FAST**	CH1_OFF	CH1_OFF	CH1_OFF	**CH1 TRICKLE**
CH2 OFF	**CH2 LED ON**	CH2_OFF	**CH2 FAST**	CH2_OFF	CH2_OFF	**CH2 TRICKLE**
CH3 OFF	**CH3 LED ON**	CH3_OFF	CH3_OFF	**CH3 FAST**	CH3_OFF	**CH3 TRICKLE**
CH4 OFF	**CH4 LED ON**	CH4_OFF	CH4_OFF	CH4_OFF	**CH 4 FAST**	**CH4 TRICKLE**

Table 3 Strobe light pulse operation

There are seven different stages (states) to the lights trigger operation, as follows;

4.3.5 Delay

This is a configurable state, it is entered whenever the microcontroller detects the incoming trigger and acts as delay from trigger acquisition to actual light output. This is used when the light is being operated in a multi spectral imaging setup. The length of this delay is configurable via a serial command. Refer to the API for details on this.

4.3.6 Pulse

This is the state where the lights actually fire. It occurs once the delay state has elapsed and its length is user configurable. It's the state where the light is on. On the Cathx Configuration software, this state is controlled via the Pulse Duration slider as illustrated in Fig.3;

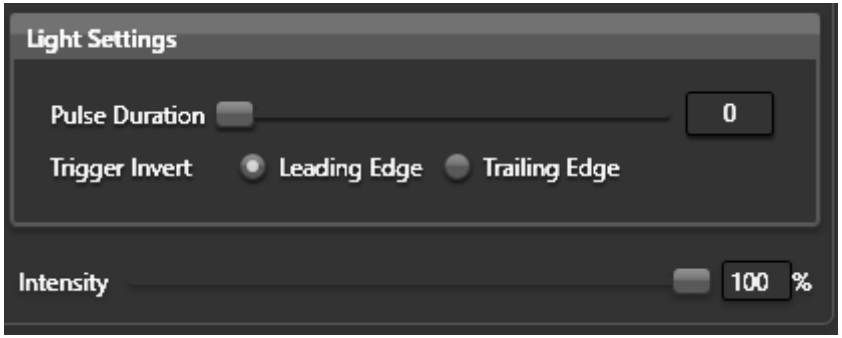

Fig.3 Strobe light settings box in the Cathx camera configuration software

4.3.7 Charge 1 – 4

These states are the channel fast charge states. The named channel is fast charged during these states. Only one channel is fast charged at a time. The fast charge current is set by the LED current control PID algorithm. The duration of the each charge interval has a limit of 56msec. The duration is calculated by the microcontrollers frame rate reading function.

4.3.8 Trickle

This state is only entered if there is enough time in the interval between pulses. During this state all channels are charged at a minimum effort. This is used to top off the channels during low frame rate operations.

4.4 Strobe Operation – Single Shot

4.4.9 Example A32 single shot configuration

The command list below will setup an A32 to operate in single shot mode where the light will be falling edge triggered. The light pulse will be set to fire for 85msec. The A32 will also auto charge once power is applied.

<C,2,auto_en 2*ZZZZ>	This command sets the light to auto charge on power up. Effective from the next restart
<C,2,s_mode 1*ZZZZ>	This command will program the light into single shot mode
<C,2,s_trigger 1*ZZZZ>	This command will configure the light to be falling edge triggered
<C,2,s_shot 85*ZZZZ>	This command will fire the LED's at full power for 85msec once the trigger is detected

4.5 Single shot mode details

4.5.10 Light output

Fig.1 shows a data grab of the LED current and voltage captured from a single channel of an A32 firing in single shot mode. The graph spans a total of 120msec. The blue line is the LED voltage and the orange line is the LED channel current. The left hand y axis measures LED voltage and the blue trace is related to this data. The right hand y axis is related to the LED current (orange trace)

In this instance the lights capacitors were charged to 46V and the pulse duration was set to 65msec. It can be seen from the graph that the power provided to the LED channel drops exponentially once the pulse begins firing. There is a plateau at the start of the pulse where the LED current is relatively constant. By 2msec into the pulse the LED current starts to drop. Increasing the charge voltage on the capacitor bank to 53V will extend this curve further.

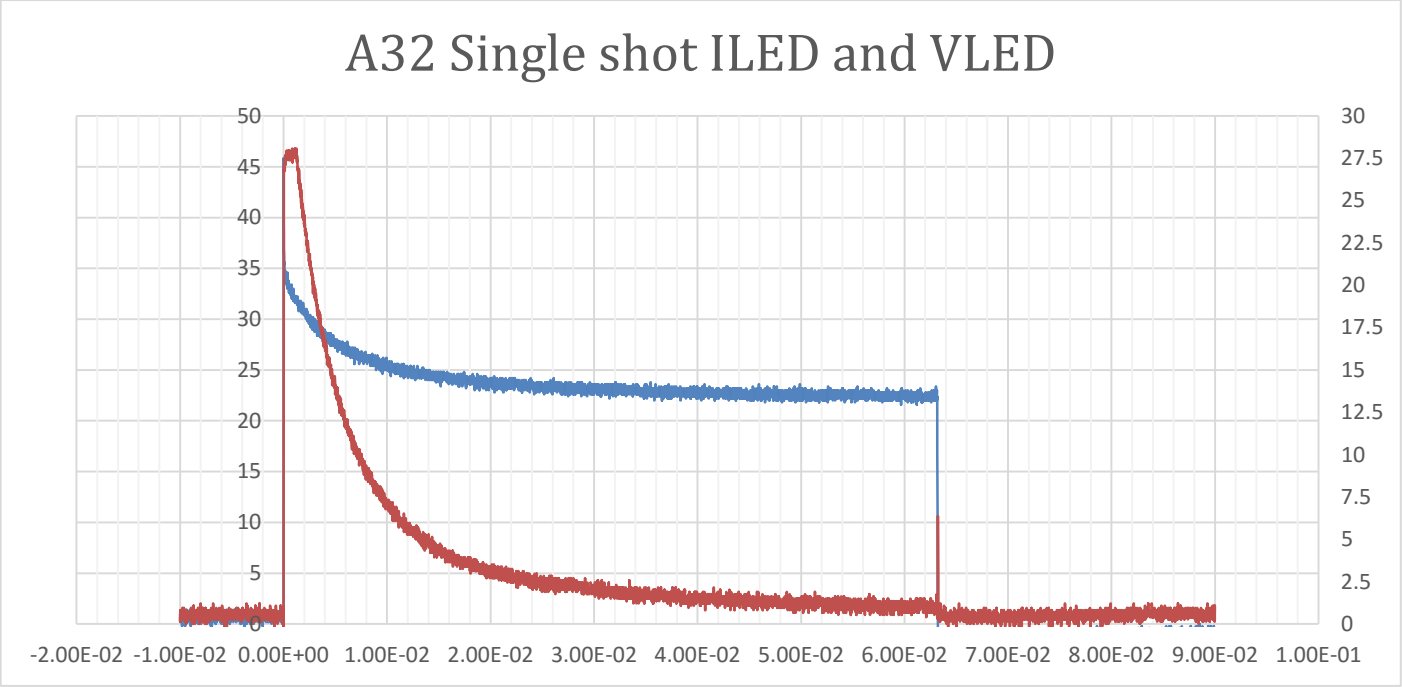

Fig.1 A32 65msec single shot trace

Although the shape of the LED current curve is a decaying exponential, it should be noted that the light LED's are on for the entire 65msec and in fact the forward current applied to the LED's is enough to maintain 100,000 lumen for the first 7.5msec of the pulse. Beyond that the lumen output is falling off but there is still considerable light being generated right up until 20msec. After 20msec the light is falling rapidly and by 65msec is low.

If the camera being used has a global shutter in place, it will have the benefit of being able to integrate all the light produced by the A32 for the entire 65msec.

4.5.11 Auto Charging

If Automatic charge is enabled the light will immediately being charging its capacitor banks once power is applied. There are 4 independent switch mode charging circuits inside the A32 bottle. Each of these is assigned to an LED channel. To prevent excessive loading when power is applied the microcontroller staggers the channel charging by 1 second. So channel 1 starts charging, the one second later channel 2 starts and so on until all four channels are charging. Once each channel reaches the target charge voltage the lights arms itself and if a trigger is received from this point onwards the lights will flash.

The advantage of auto charging is that the light does not need any software intervention to fire. Once the lights have charged all you need to do is apply the trigger and the light will fire according to its programmed parameters.

4.5.11.1 Bench top method for Determining when the light is ready to fire

Before leaving the factory all lights have their auto-charge time measured and entered into the build configuration documents that accompanies the light. If you don't have that, there is a method of determining the auto charge time, this requires an RS485 interface to the light.

1. Turn off the light and leave it off for at least 10 minutes.
2. Start-up Putty (or whatever command line tool you use)
3. Enter the following command but do not press enter on the keyboard <C,2,rep_vcap 1*ZZZZ>
4. Get a stopwatch ready.
5. Power on the light and wait approx. 3 seconds. Press enter on the keyboard to send down the last command and start your stopwatch.
6. As soon as the light has auto charged it will output 4 lines on the screen detailing the voltage on each channel. Stop your stopwatch when this appears.
7. The elapsed time is the auto-charge duration, with some error in terms of the 3 second delay at the start.

4.5.12 Re-arming the light in single shot mode

The single shot mode developed for the A32 was designed to be used on a permanent installation where power conservation is a key requirement. In normal 'pulsed' mode, once the LED's fire the A32 immediately begins recharging its capacitor banks. In single shot mode, once the LED pulse is over the light internally shuts down; it disables its trigger input and does not recharge its capacitors banks. This minimises the power drawn from the light once the LED's have fired. To re-arm the light for the next pulse you must power cycle the light.