New Headlamp System Design

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This paper discusses a new headlamp and shadow light concept that uses a sophisticated control system that allows you to easily control multiple beams to generate an optimal quantity and distribution of light so you can safely and conveniently accomplish your task.

Although the market is flooded with headlamp designs, none of the headlamps on the market address the specific control issues I am addressing here. Nor are there any lighting systems that address the rough terrain issues I am addressing here.

Basic System Design

The purpose of a headlamp is to provide hands free illumination and to allow the light to follow head movements so the light is always pointing in the general direction of where you are looking. The purpose of a shadow light is to add visual contract to uneven terrain.

The normal mounting position for a headlamp is around forehead level and roughly centered. The forehead location is normally chosen out of convenience. However, there are many other possible positions around the head, including at the side of the face or under the chin.

Here is a list of design goals for the lighting system:

- Hands free illumination
- Optimum quantity and distribution of light to accomplish tasks
- Easy to operate – quick and simple adjustability as tasks change
- Sophisticated control system – does what you want
- Avoids over and under illuminating the scene
- Protects dark adaptation from sudden increases in reflected light
- Compensates for dark adaptation when transitioning to darker environments
- Improved terrain information through highlighting and surface shadowing
- Long run times between battery changes
- Extended low battery warning – no unexpected forced battery changes
- Emergency signaling
- Reasonable size and weight
- Elevation (tilt) adjustment
- Reliable operation in harsh environments
- Rechargeable battery system with replaceable batteries

A task can last from under a minute to over an hour. For instance, there are many possible tasks you may perform during a night hike: hiking, reading a map, eating a snack, locating an appropriate campsite, setting up camp, gathering fire wood, preparing a meal, eating a meal, washing dishes, writing in your journal.

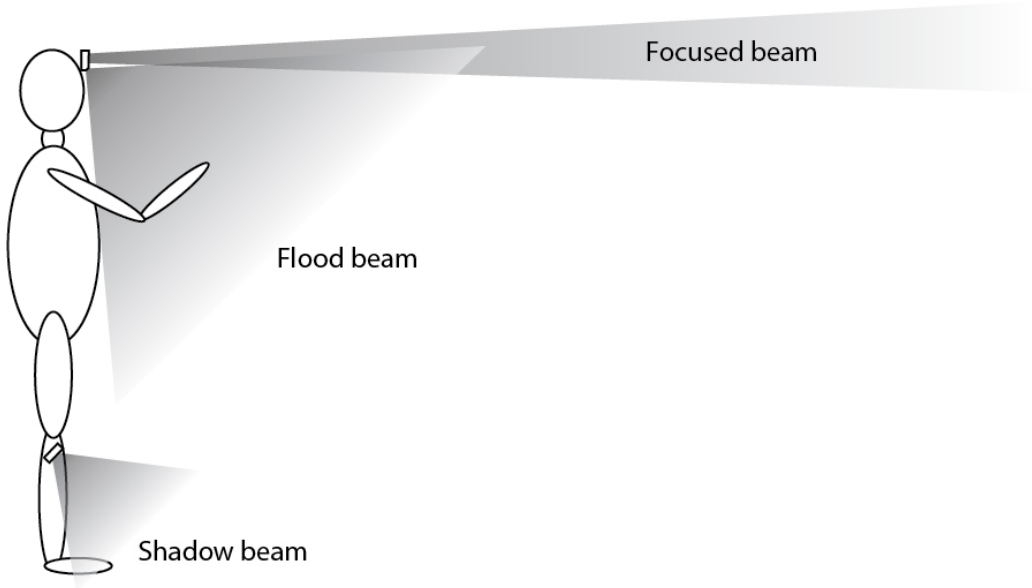


Illustration of a light system consisting of a focused headlamp beam, flood headlamp beam and an optional flood shadow beam.

A focused beam is great for putting lots of light down range and enabling you to see a long distance.

If you are standing up, the line of sight to a distant object will be roughly perpendicular to your body. And thus the axis of the focused beam will be roughly perpendicular to your body when illuminating a distant object.

It can be difficult to see objects outside a narrowly focused beam due to excessive contrast from the bright central beam to the dim outer edge. This can force you to scan the area in front of you to see objects outside of a narrowly focused beam. Having a better distribution of light between the focused central spot and the outer areas of the focused beam can minimize the need for scanning and improve the utility of the focused beam.

A flood beam is great for seeing a wide field of view. The beam illumination is fairly constant from the center of the beam to the outer edge of the beam generating a fairly low contrast across the beam. Thus it is easy to see all the objects within a large field of view without moving the beam.

If you are standing up, the line of sight to most close objects will be tilted downward. This is true whether you are holding something in your hands, performing activities done within arm's length or observing the ground immediately in front of you. Your eye's natural field of view also happens to be tilted downward.

The flood beam should be angled downward roughly 30° from the focused beam to generate a more useful light distribution. In other words, the focused beam should be oriented closer to the top of the flood beam. The downward tilt of the flood beam also aligns the flood beam with your natural field of view for maximum utility.

Here is a summary of the basic headlamp design features:

- Two beams: one focused and one flood.
- The flood beam's axis will be tilted downward roughly 30° below the focused beam's axis.
- Each beam is controlled by an independent channel.
- Each channel can generate an adjustable amount of light with a range of control from maximum to minimum plus off.
- Sophisticated function controls are created on top of the channel interface and include: independent control of each channel; adjustable blending of the channels; adjusting total brightness while maintaining the blend; selecting from a list of presets; sharing an interface control between multiple functions; automatic dark adaptation compensation and protection.

The design of the optional shadow light is covered later.

The Concept of a Control

A control is a device that can be manipulated to generate more than one value. The control may be manipulated through user interaction, environmental sensing, software algorithms, timed events or other means. Basic controls can be classified into two broad groups: dual-position and multi-position. Basic controls may be combined to create more advanced compound controls. More advanced controls can have multiple inputs and/or multiple outputs.

A basic dual-position control has two values – e.g., 0 and 1. Examples of dual-position controls include pushbuttons and toggle switches.

A basic multi-position control has three or more values – e.g., 1 through 30. An example of a multi-position control is a rotary control, where the rotational position of the control generates the control's value.

A compound multi-position control can be implemented using dual-position controls for input. For example, you can use two pushbuttons to implement a

bidirectional multi-position control – pressing the first button moves the control in one direction and pressing the second button moves the control in the opposite direction.

A compound multi-position control can even be implemented using a single dual-position control for input. For example, pressing the pushbutton moves the control in one direction – using a double-click or other construct, the control direction reverses so that pushing the pushbutton now moves the control in the opposite direction.

A button command interface is an example of a compound control with multiple inputs (e.g., pushbutton, timers and state information) that generates multiple outputs (state information and actions).

A control may also include (or be driven by) a sensor. For example, you can use a light sensor to detect the illumination level and generate a corresponding set of control values.

The set of values generated by a control can be arbitrary. Although our prior examples used sequential integer sets, each control position may be assigned an arbitrarily value. The only requirement is that the control must be deterministic. That is, if a control is provided with the same input, it must select the same control position and generate the same output value.

I wish to differentiate between bidirectional controls and unidirectional controls. A unidirectional control requires that you scroll through all control positions in order to move backwards one control position. This is inconvenient and gets worse as the number of control positions increase. Multi-position controls should always be bidirectional – i.e., you should be able to move them in either direction with similar ease.

The Concept of a Channel

A channel is the control system for regulating an individual beam's brightness. The illuminating device is part of the channel. The channel accepts an input of some kind and generates a corresponding beam brightness as its output.

The channel can use digital and/or analog methods to regulate the beam brightness – there are many known regulation methods available.

Physical Versus Logical

It is useful to differentiate between a physical thing – something that can be touched – and a logical thing – something that only exists in software. A physical thing is

limited by the laws of physics whereas a logical thing can do anything you can create a software algorithm to accomplish.

A physical control is a control that can be physically manipulated. A physical control includes all of the hardware needed to generate its set of values. Examples of physical controls are pushbuttons, rotary encoders and sensors.

A logical control is an abstraction – a virtual representation of a hypothetical control. Only software can manipulate a logical control. However, you can connect the output of a physical control to the input of a logical control via software.

A logical control allows you to create an idealized control that performs an arbitrary function – i.e., it can do exactly what you want. The possible operations of a logical control are not constrained by the limitations of physical hardware. A logical control can do anything you can write software algorithms to accomplish.

A common use for logical controls is to build a single pushbutton command interface consisting of short clicks, longer presses and state information to allow the user to access a large number of functions from a single pushbutton. Common functions include selecting preset brightness levels and programming capabilities.

In the case of the single pushbutton command interface, there is one physical pushbutton that is used to drive a compound logical control – which is the command processor. You are actually sharing the pushbutton between multiple functions.

The concept of sharing includes multi-position controls. You may have limitations on implementing enough physical controls due to cost, space, reliability, convenience or many other factors. For instance, let's say you have only one rotary control but you have multiple multi-position control functions that the user can manipulate. You need to share the single rotary control with the many logical multi-position control functions.

The process of sharing is normally done through the common technique of multiple modes of operation. For instance, in mode A the rotary control is associated with logical control function A while in mode B the rotary control is associated with logical control function B.

A logical control can be controlled by multiple physical controls, allowing the physical controls to work together with the logical control as a single compound control. An example would be the two pushbutton multi-position control mentioned earlier.

Physical and logical controls can be compounded in arbitrary ways to build sophisticated control systems to accomplish whatever the design requires.

A logical channel is a thing that only exists in software – a virtual representation of a hypothetical channel. Software manipulates a logical channel and the logical channel then drives the physical channel hardware to regulate the output brightness.

A logical channel is an abstraction that allows you to create an idealized channel that performs an arbitrary function – i.e., it can do exactly what you want. This allows the logical channel to compensate for limitations in the hardware. For instance, a logical channel can compensate for nonlinearities in the physical circuitry. Or a logical channel can take a linear input and generate a logarithmic output. Or a logical channel can virtualize the feedback and regulation process.

Historic implementations of channels with variable outputs typically used hardware to directly regulate the output level. If a logical channel was used at all, it was only used to modify a circuit feedback parameter used to set the output level. In other words, the logical channel may have selected the output but the channel hardware was still directly regulating the output.

A more advanced method of implementing a channel is to move all of the feedback and regulation control into software – into the logical channel. In such a system, the logical channel will take care of sensing circuit parameters and use software algorithms to operate output switches directly. In other words, there is no hardware regulation remaining – we have completely virtualized the channel regulation.

When using logical controls and logical channels, there is no physical connection between the physical controls and the physical channels. Software algorithms – not physical hardware – are used to make the connection. Think fly-by-wire.

Dark Adaptation

Your eyes are very adaptable and able to accommodate the huge dynamic range between noonday sun and moonlight. Your eyes use two primary methods to accommodate this huge dynamic range: the iris controls the total amount of light allowed to enter the eye while the retina controls how sensitive the eye is to the light it receives.

Dark adaptation generally refers to the process your eyes go through to increase their sensitivity to light and assumes the iris is already fully open. Cones (color vision) increase sensitivity much faster than the rods (gray-only vision). The first stage of dark adaptation takes around 7 minutes – the amount of time it takes the cones to gain most of their sensitivity and for the rods to exceed the cones in sensitivity. During the second stage, the rods continue to increase their sensitivity over the next 20 – 30 minutes. You will notice the rate of adaptation starts off rapid and then tapers off – see the sensitivity illustration below.

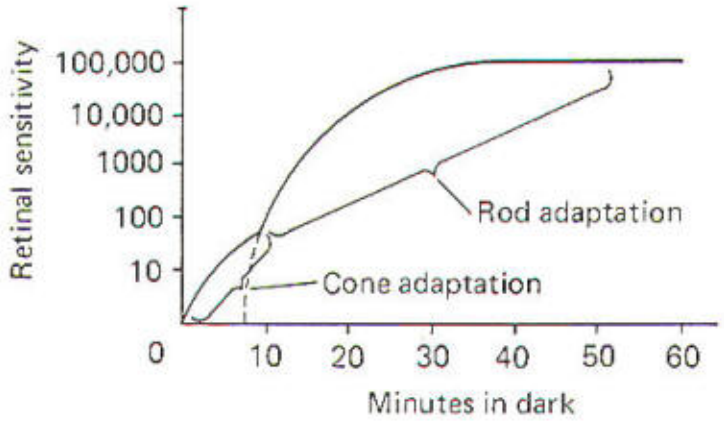


Illustration of cone and rod sensitivity during dark adaptation.

You should note that there are significant differences between individuals in their ability to dark adapt. And an individual's current state of health can affect the individual's ability to dark adapt.

The preset levels in a light are chosen with optimum dark adaptation in mind. If you transition rapidly to a darker environment – whether by entering a darker environment or reducing the output brightness, the selected level may not provide sufficient light to safely perform tasks during the early stages of dark adaptation.

It is possible to compensate for the lack of dark adaptation by temporarily increasing the brightness as the environment darkens and then slowly reducing the brightness back to the selected level as dark adaptation takes place. This ensures you have sufficient light under all conditions of dark adaptation.

A similar but opposite situation occurs when the lighting system provides too much light for the local environment. With too much light added to the environment, surface illumination levels increase and your eyes loose their dark adaptation. Depending on the brightness and duration of the illumination encountered, you can loose significant dark adaptation in a matter of seconds.

What is needed is a system that understands the eye's dark adaptation characteristics and monitors the recent exposure to light so the system can estimate the current level of dark adaptation and preserve it or compensate for it.

The most problematic situation occurs when a focused beam is moved from a distant object to a close object. The increase in surface illumination can be both dramatic and rapid. A flood beam is much less problematic. When the general illumination level increases quickly, the system should determine what part of the increase is resulting from which beam and quickly reduce the brightness of each beam appropriately to preserve your dark adaptation. With proper algorithms, it is

even possible to tell the difference between a beam reflection that you have control over and an exterior light source that you can't do anything about.

Special algorithms are needed to monitor ambient light levels, to characterize your eye's dark adaptation response and to adjust the output brightness of the selected brightness to compensate for changes in the environment.

Sophisticated Control Functions

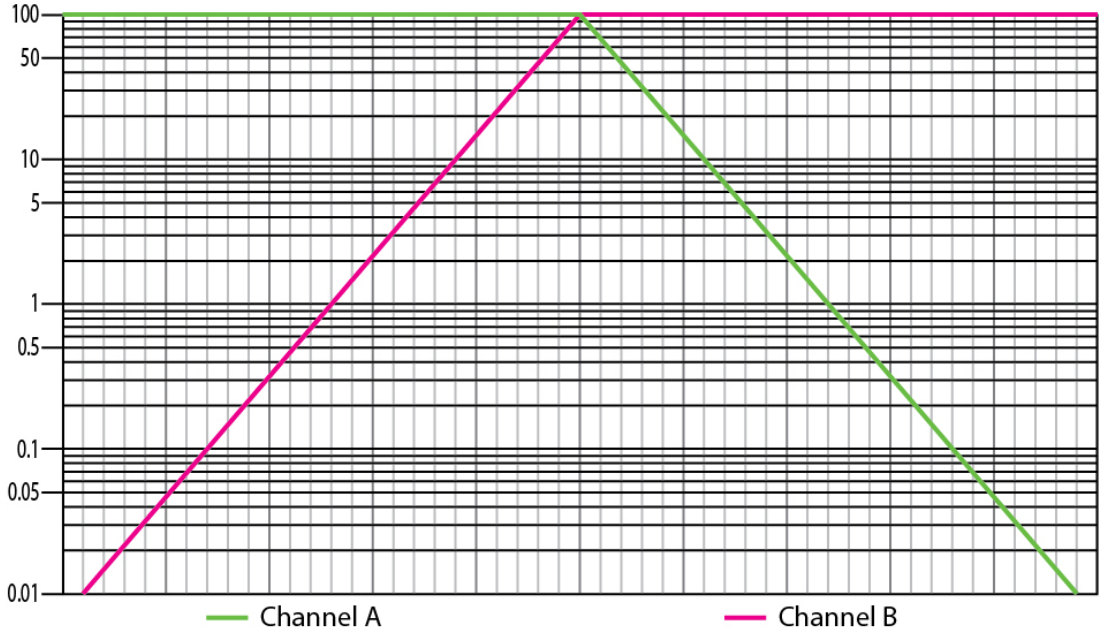
Once the physical controls and physical channels have been disconnected and abstracted with logical controls and logical channels, you can build a sophisticated control system to control the headlamp. The software takes care of reading physical controls, uses those readings to operate logical controls and then uses the logical controls to operate the logical channels, which in turn control the physical hardware to control the beams.

The following is a summary of the anticipated sophisticated control functions. We assume we have at least one dual-position control and at least one multi-position control that the user can manipulate. The preferred implementation is a momentary pushbutton for the dual-position control and a rotary encoder without mechanical stops for the multi-position control.

The first sophisticated control function is a command system for selecting features, modes and options using a single pushbutton. A synopsis of the command structure is given later.

The second sophisticated control function is to share a single multi-position control between multiple logical multi-position control functions. This can save money by reducing the total number of physical controls at the expense of adding operating modes and user interface complexity.

The third sophisticated control function is the blend function. The blend function makes it possible for a single control to move through all possible combinations of the two channels in an orderly manner. For example, at one extreme, channel B is off while channel A is at maximum. As the control moves to the center, channel B ramps to maximum while channel A remains at maximum. Both channels are at maximum at the control's center. On the other side of center, channel B stays at maximum while channel A ramps down to minimum and then off at the other control extreme. See the Blend Function illustration below.

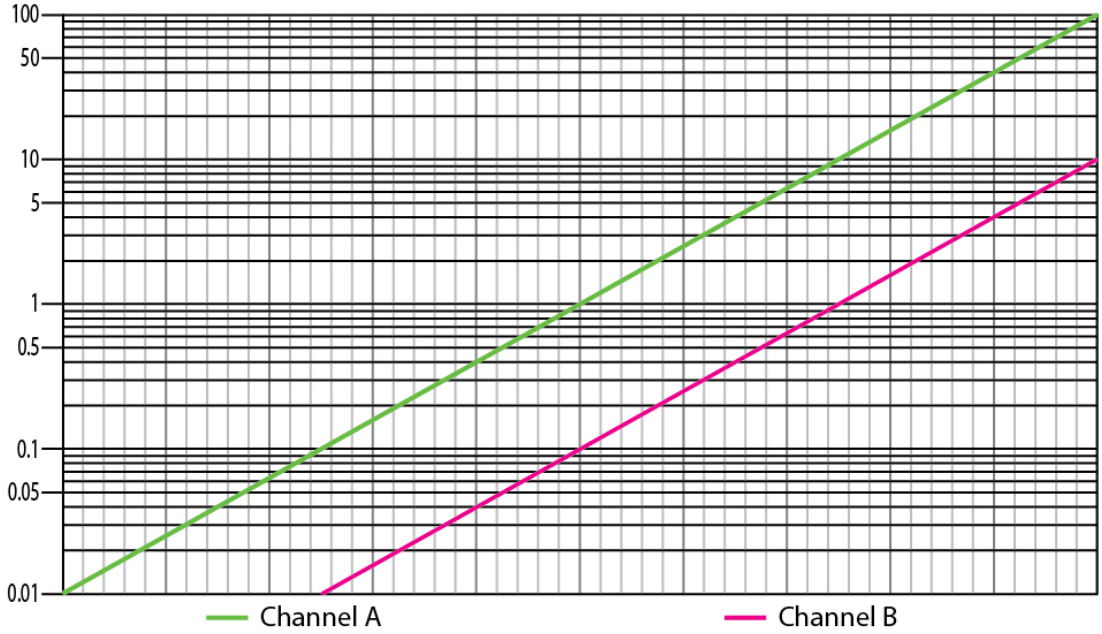


Blend Function. This diagram illustrates the relative outputs for the two channels as the blend control is moved through the control's range. Each channel has an off position next to the minimum position. The X-axis is the control's range. The Y-axis is log percentage output.

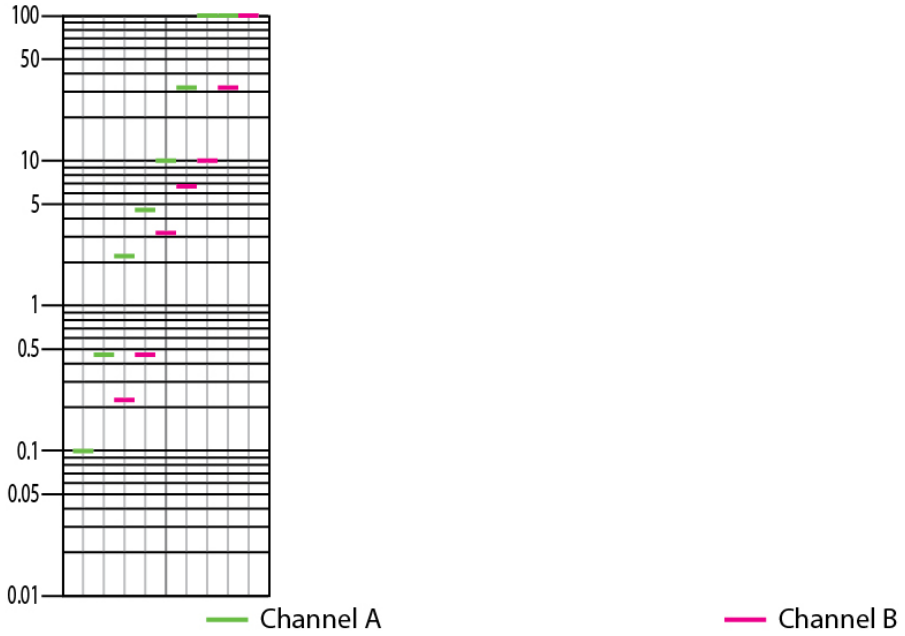
The fourth sophisticated control function is the total brightness function. The total brightness function makes it possible for a single control to change the combined output brightness while keeping the blend the same. See the Total Brightness Function illustration below.

The fifth sophisticated control function is the preset list function. If you only need a small number of combined channel settings, it may be more convenient to set up a list of those presets and then select the desired preset from the list. A programming interface is provided to add, delete and modify presets. See the Preset List Function illustration below.

The sixth sophisticated control function is the basic ability to directly adjust each channel independently. A direct adjustment control allows a channel to be adjusted to any output brightness – from maximum to minimum, or off – without affecting the other channel. One control is required per channel.



Total Brightness Function. This diagram illustrates how the blending between the two channels is maintained as the total brightness is adjusted for one possible blend setting. The channel at 100% blend is scaled from minimum to maximum. The second channel maintains the selected blend relation to the first channel. The X-axis is the control's range. The Y-axis is log percentage output.



Preset List Function. This diagram illustrates one possible set of presets. For the purposes of this illustration, channel A is the flood beam and channel B is the focused beam. The X-axis is the control's range. The Y-axis is log percentage output.

The seventh sophisticated control function is for dark adaptation compensation and protection. This control automatically senses a significant change in light and compensates. In the case of a dramatic decease in light, the selected output brightness is increased to compensate for a lack of dark adaptation – slowly returning to the selected light output over a period of time. In the case of a dramatic increase in light, both the blend and total output will be adjusted to preserve dark adaptation, returning as needed to the selected light output over a period of time.

The eighth sophisticated control function is to automatically turn off the light when returning to a very bright environment.

We have only listed 8 obvious sophisticated control functions. This is not intended to be an exhaustive list. The 8 we have listed happen to be part of the anticipated initial implementation.

The sophisticated control system will typically use relative position controls. From the user's perspective, relative position controls do not use mechanical stops. If you move a relative position control past the end of a control's range, the control simply retains the end of range value and ignores the additional control movement. In the case of a circular control, moving past one end repositions you at the opposite end.

Relative controls are very convenient when sharing a multi-position control. The shared control is (essentially) only conveying relative movement information to the underlying logical control so neither cares about the other's value. Changes in position are what matter. That allows you to switch between logical controls without concern for the shared control's position or the position of any logical control sharing the shared control.

With sophisticated control functions, adjusting one control may affect the settings of other controls. This is done for the convenience of the user. If the user switches from using one function to using a different function, the user expects the transition to be seamless – i.e., the new function should continue from the current output setting without obvious glitches. An example may be helpful. A user can start by selecting a preset. The user can then switch to the blend function and seamlessly adjust the blend. The user can then switch to the total brightness function and seamlessly adjust the total brightness.

If there is no exact mapping between control functions, the closest mapping will be used. For instance, the direct channel function, the blend function and the total brightness function do not directly map to the presets list so the software must pick the closest preset in the list to approximate the result of the other functions.

The act of switching to a different control function does not change the output. The output is only changed in response to that function's control being manipulated. For

instance, selecting the preset list function does not change to the nearest preset. The output only changes when the user manipulates the preset list's control – i.e., when the control is moved to the next or previous preset.

The blend operation can be made to always maintain the same total brightness. However, it requires artificially limiting the combined output of both channels to half of the unlimited combined total output and changing the blend graph. It is then possible to guarantee that as one channel is increasing in output, the other channel is decreasing in output by a corresponding amount. However, the potential marketing downside caused by artificially limiting the total output may not justify any real or perceived benefits.

Shadow Light Design

The problem with placing your primary light source in close proximity to the visual axis (e.g., close to your eyes) is that the resulting scene lighting is very flat. Surfaces at similar distances are illuminated to similar levels so there is very little visual contrast. Further, any shadows present will be tiny and visually insignificant.

The primary benefit of the shadow light is the increase in visual contrast of irregularities along the path of travel. This is done in two ways. First, the sides of irregularities closest to the light are brighter while the sides of irregularities furthest from the light are darker. Second, significant irregularities will cast shadows – potentially long shadows. Since the axis of the shadow light is approaching perpendicularity to the visual axis and is far away from the eyes and relatively close to the ground, this significantly increases the visual contrast of irregularities. In other words, the shadow light highlights irregularities and makes them visually obvious.

A second benefit of a shadow light is the ability to illuminate the area immediately in front of your feet independent of where the headlamp is pointed. A third benefit of a shadow light is the relatively low power required due to the light's close proximity to the area being illuminated.

The shadow light must be mounted well below eye level to accomplish its task – the lower the better – up to a point. The optimum height is generally considered to be around fist height – which is roughly around the middle of the upper leg and is as far away from your eyes as you can hold your light. This height represents a good compromise given practical considerations.

A shadow light attached to the lower half of the body is subject to orientation instability. As a result, the shadow light should utilize a flood beam pattern so orientation changes will not cause distracting bright spot motions. Hand holding a shadow light at fist height will provide a stabilized orientation and cast great shadows but violates the hands free criteria for the design.

Picking the optimum location for the shadow light is mostly an issue of picking the least bad location. The biggest problem with mounting a shadow light to the lower body is keeping the light out of the way. For instance, in caving, mounting a light to the front surface of the body will interfere with crawling.

Another issue with the shadow light placement is that moving body parts – e.g., legs, hands and feet – can cast shadows as you walk. Careful positioning of the lights will minimize unwanted shadows. You can minimize the remaining shadows by using at least two shadow lights – one light fills in the shadows created by the other.

Another issue with the shadow light placement is that moving body parts – e.g., legs, hands and feet – can move in and out of the beam causing significant illumination changes within the field of view. You can minimize these illumination changes by carefully positioning the shadow light(s).

Another issue with the shadow light placement is locating the light too close to the feet. As each foot lifts, swings forward and is placed back down, there is a huge amount of relative movement and elevation change. Even with a flood beam, it is difficult to smooth out the large brightness variations generated by these movements.

Finally, the light source for the shadow light must be shielded so it is not in the field of view under normal use. Having a bright light in the field of view is distracting – not to mention annoying.

Mounting the shadow light just below the knee and to the outside of the leg using a strap system appears to be a fairly optimum arrangement.

The main headlamp can control the shadow light. An example of how to accomplish this is by using a Bluetooth wireless system. However, it may be more practical to have the shadow light completely independent of the main headlamp. Very little utility is gained by allowing the main headlamp to control the shadow light – especially when you consider the added complexity. However, there may be certain markets where the added utility and convenience are well worth the added complexity.

Another option would be to have a separate remove control that controls the shadow light (and possibly the headlamp), perhaps using Bluetooth. But again, this may be more trouble than it is worth – adding significant complexity for a marginal gain in utility. However, there may be certain markets where the added utility and convenience are well worth the added complexity.

Usage Scenarios

Here are several scenarios to illustrate the use of this system.

- Utility worker, electrician, plumber, etc. Use a medium flood and no (or low) focused beam to illuminate the immediate work area. You have plenty of light for doing detail work and long runtimes that can easily accommodate a 24-hour shift plus a generous safety margin.
- Walking along a rough trail. Use a medium flood and low focused beam to clearly see the obstacles directly ahead. The low intensity focused beam illuminates the area well in front of you without over illuminating the scene and the spill of the focused beam combines with the flood beam to provide a smoothly illuminated area from your feet to a useful distance in front of you. An optional shadow flood beam highlights trip hazards and improves travel over rough terrain.
- Trail running. Use a high flood and medium focused beam to give you good visibility of the terrain you are about to encounter. Two optional shadow flood beams – one per side – provide increased 3D terrain information. Traveling at a higher speed requires more light so you can see further ahead – allowing you sufficient reaction time to plan your path and avoid obstacles.
- Surveying in a cave. Use a low flood to take notes and sketch. You can switch to a medium focused beam to look at medium distance objects or switch to a high focused beam to look at more distant objects.
- Sitting around waiting. Use the very low flood. The power consumption at this light level is very low so there is no reason to sit in the dark unless you really want to be in the dark.
- When looking at distant objects with a bright focused beam, you may tilt your head down, which brings the beam very close, seriously over illuminating what the beam touches. The headlamp automatically compensates and temporarily reduces the focused beam output to protect your dark adaptation.
- You enter a darkened area from a brightly lit area so your eyes are insensitive to light. Your normal settings are too dim for insensitive eyes. Dark adaptation compensation automatically increases the total brightness and then slowly decreases the brightness over a period of time to give your eyes time to adapt to the dark.
- You exit a cave, mine or unlit dark building into daylight and forget to turn off your light. The light automatically notices the light is no longer needed and turns off after an appropriate delay.

Detailed Design Specification for Headlamp

The following is a detailed design specification for one possible headlamp implementation employing a single pushbutton control and a single rotary control:

- Nicely sculpted – attractive to look at
- Split design, single replaceable 18680 (18650) rechargeable battery
- Target weight: 8oz – spit between light, cord and battery compartment
- Target runtime: 30 hours at 30 lumens
- Wire sealed at both ends, no central plug
- Wire exits light and battery compartment at angle to eliminate sharp bend
- Fully sealed, IP67, waterproof to 20m (66 ft)
- Conformal coated electronics – water and shock proof
- Separate flood and spot beams, flood tilted down about 30°
- Independent logarithmic channel for each beam
- Full variable control over each channel including off
- Single momentary pushbutton control
- Single rotary control, no rotation stop
- Magnetic coupling between the knob and rotary control
- Click on – click off
- Turns on to a settable preset and mode
- On: press and hold goes momentarily to a settable preset (maximum)
- On: double-click toggles modes A and B or return to last used mode A or B
- Mode A: total brightness function
- Mode B: blend function
- On: triple-click goes to mode C
- Mode C: list of presets
- On: click, press, hold, release toggles dark adaptation features, short green when enabled, short red when disabled.
- Off: click, press, hold, release to enable emergency signal. Remembers last signal used. Rotary control selects signal: slow-speed flash, high-speed flash and SOS, uses focused beam channel with automatic dark adaptation off.
- Blend: one channel is at 100% while other channel varies relative to 100%
- Total brightness: scales both channels simultaneously maintaining blend
- Each preset contains the two channel values and the dark adaptation setting
- Reset: turn light on and remove battery or remove battery for 5 minutes. 7 second reset indication.
- Factory reset – reset, press and hold during indication until light goes out.
- 20-click, press and hold following reset indication to enable menus.
- On: double-click, press, hold, release to enter preset menu.
- Preset menu: select preset in mode C, enter menu, double-click to toggle rotary control function, use rotary control to adjust flood and focused levels, click, press, hold, release to toggle dark adaptation features, press and hold to

set. Set both to off to delete preset. Triple-click to insert duplicated preset after – you are editing inserted preset.
- Preset list supports 1 to 30 presets, room for multiple sets and separators
- On: triple-click, press, hold, release to enter option menu.
- Option menu: use rotary control to select option, green when enabled, red when disabled, yellow between options, white coding indicates option, press and hold to toggle (red/green also toggles) or set, turns off when complete
- Options: set turn-on preset to current settings, set momentary preset to current settings, enable button lockout (3 clicks from off), enable locator flash (4 clicks from off), enable burst, enable mode C circular, enable mode C wide rotation spacing, show battery indication when on, show battery indication when turning off, disable menus.
- State of charge indicator – assume linear drop – two color LED – green to 80%, alternating green/yellow to 60%, yellow to 40%, alternating yellow/red to 20%, red to 5%, blinking red to 0%. No compensation for temperature or current draw, so indicator will show lower capacity on higher settings and at lower temperatures, which is correct.
- Automatically turns off after returning to a well lit environment

Detailed Design Specification for Shadow Light

The following is a detailed design specification for one possible shadow light implementation:

- Nicely sculpted – attractive to look at
- Single 18680 (18650) rechargeable
- Left or right-hand mounting
- Flood beam pattern
- 10 logarithmically spaced brightness settings
- Single button interface
- Click on, click off – remembers last brightness setting used
- On: press and hold to increase/decrease output – increase is default direction
- On: double-click to reverse direction

Currently Available Competing Designs

There are many headlamps, bicycle lights and flashlights on the market. In searching though the vast number, I have noted examples that have certain aspects of similarity to my design as these represent prior art and disqualify those aspects of my design from qualifying for patent protection.

Two beams – one focused, one flood. The Scurion headlamp can do this. The Klarus FL18 has a main beam and a separate diffuse beam that is 90° to the main beam.

Beams pointed in different directions. The Scurion headlamp can do this. The Klarus BK30 bike light has two emitters on adjustable side swivels in addition to the main beam. The Klarus FL18 has a main beam and a separate diffuse beam that is 90° to the main beam.

Each beam assigned to a separate independent channel. The Scurion headlamp and Klarus BK30 can do this. The Scurion headlamp has 4 brightness levels plus off for each channel.

Independent adjustability of each channel. I did not find any examples of independent adjustability that were bidirectional. The Scurion headlamp and Klarus BK30 can adjust each channel independently but the operation is unidirectional.

Blend control. I did not find any examples of lights that provided a control for changing the ratio between the beams. Note: although the Scurion and Nora headlamps can be programmed to simulate a blend control, this is not the design intent of their control and I do not view them as having a blend control.

Total brightness control. I did not find any examples of lights that provided a control for simultaneously adjusting total brightness while maintaining the current blend. Note: although the Scurion and Nora headlamps can be programmed to simulate a –very– crude total brightness control, this is not the design intent of their control and I do not view them as having a total brightness control.

Programmable presets control. The Scurion and Nora headlamp can do this. They are fully programmable and provide up to 10 separate combinations in the control range. Presets can be added, deleted and modified.

Shared multi-position controls. I did not find any lights that had shared multi-position bidirectional controls.

Relative multi-position controls. I did not find any lights that provide relative controls. I do not view the Scurion and Nora interface as providing relative controls even though the preset control wraps around in both directions and the number of items in preset list can change.

Automatic scene illumination. The Petzl Nao can do this but requires an app to configure the parameters. Surefire P2X Fury with IntelliBeam Technology but the setting is fixed. There are many issued patents that try to cover this technology. It will take additional research to determine which of those patents may apply and which of those may be valid. We use expanded aspects of this technology for dark adaptation preservation so existing patents may not apply.

Dark adaptation. I did not find any lights that provide dark adaptation compensation. Although I am not aware of any patents that pertain to this, there might be a patent that covers some part of this. It will take additional research to figure this out.

Shadow light. I did not find any shadow lights. I owned a Matex Safety-Lamp (Matobe, Japan) bicycle leg light back in the 70s that strapped to the upper calf – i.e., just below the knee with a white light forward and a red light rearward. There are many "visibility" ankle and arm lights available – intended to make you visible – but not intended to illuminate obsticles.

Points of Distinction

There are several aspects of my lighting system that do not appear to have "obvious" corresponding examples in existing products:

- Shared bi-directional multi-position controls
- Relative bi-directional multi-position controls
- Blend function
- Total brightness function
- Bidirectional independent channel adjustability
- Dark adaptation compensation
- Shadow light