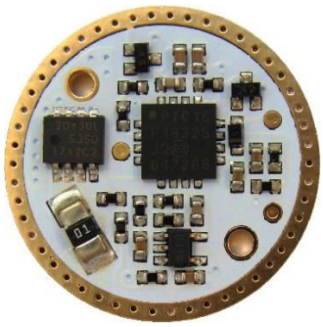
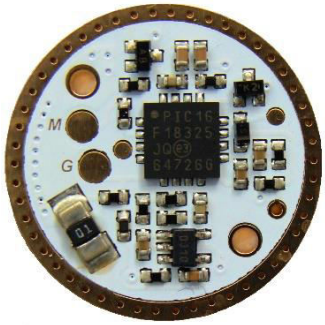
LD-4 series

2-12A 17mm constant current LED drivers





LD-A4/B4 2-12A constant current („PWM-less“) LED drivers are next generation of LD driver series. Based on completely re-designed hardware and improved firmware, these drivers are optimized for single-cell (4.2V) flashlights, and offer some new features compared to LD-3, like hardware (real) direct drive mode option, 1-wire temperature sensor support, integrated moonlight with 3 levels (2.5mA, 5.0mA, 7.5mA) adjustable via user interface, and low current bleeding support for illuminated tailcap modules like ILC-1. Typical bleeding current is just 1mA, which is 5-10 times lower than conventional resistor bleeding. This enables significantly longer run times on moonlight modes.

LD-A4 is standard type of linear driver with all components on PCB, designed for power dissipation 2W - 6W@60C. Recommended applications are single Li-ion cell LED flashlights with single LED.
LD-B4 is designed to work with external power MOSFET (source of heat) for much higher power dissipation – up to 15W@60C, which is more than enough for any triple or quad LED setup. “MOSLED” high performance metal core PCBs have space for MOSFET and NTC sensor, which makes triple or quad LED builds fast and easy, and more important – reliable because of real constant current driving/limiting.

Hardware features:

- True PWM-less constant current (all modes)
- Available as 3, 6, 9 and 12Amps version – 2-12Amps possible by adjusting current in UI
- Completely silent – no acoustical or EMI noise („whining“)
- Longer run-times on lower modes compared to PWM drivers
- Higher overall lm/W efficiency on lower modes compared to PWM drivers
- Lower losses in springs, wires, switch compared to PWM drivers
- Very low internal resistance comparable to best DD drivers
- Hardware DD mode option on high mode without current limit
- Calibrated internal voltage reference and temp. sensor
- Dual over-temperature protection (internal, and external [NTC] sensor) – single wire NTC connection
- Integrated moonlight with UI selectable 2.5mA - 7.5mA current
- Low sleep current
- Improved Off-time mode memory circuit
- Low current (1mA) bleeding support for illuminated tailcaps
- Single-sided PCB with large (9mm) spring pad on bottom side
- 4-layer gold plated PCB
- Lead free

User interface features:

- 2-level depth configuration menu with back/cancel option – possibility to change many settings without leaving configuration mode
- Adjustable current (without any resistor change):
  0.125Amp steps (3A version) down to 2A;
  0.250Amp steps (6A and 9A version) down to 4A (6A version) and 7A (9A version):
  0.500Amp steps (12A version) down to 8A
- 1-5 modes mode – groups
- Moonlight 2.5mA – 5.0mA – 7.5mA/Disable
- Mode memory Enable/Disable
- CC/DD Enable/Disable for high. mode (Constant current/Hardware Direct Drive)
- Mode order Forward/Backward
- 2x or 3x tap special function – Tactical strobe/High mode/Disable
- External over-temperature(OTP) threshold setting – Factory/Custom/ Disable
- Configuration mode password Enable/Disable
- Factory reset

Electrical characteristics:

- Input voltage: 2.8V-4.35V
- Output current: 2-12 Amperes (3A,6A,9A,12A default options)
- Switch type supported: reverse clicky switch
- Internal resistance: 5mΩ@3.7V
- Sleep/off current: 20uA typ. (40uA typ. with ext. NTC sensor) /1mA with low current bleeding
- Active state (operating) current: 1.6mA typ. (2.6mA typ. with low current bleeding)
- Tailcap bleeding current consumption: 1.0mA typ.
- Driver internal OTP protection threshold: ~105°C
- Default external sensor OTP threshold: ~65°C
- Step 1 LVP threshold: 3.0V (restricted power)
- Step 2 LVP threshold: 2.8V (shutdown)
- Configuration menu level 1 (main menu) current: 350mA
- Configuration menu level 2 (sub-menus) current: 100mA

Mechanical characteristics:

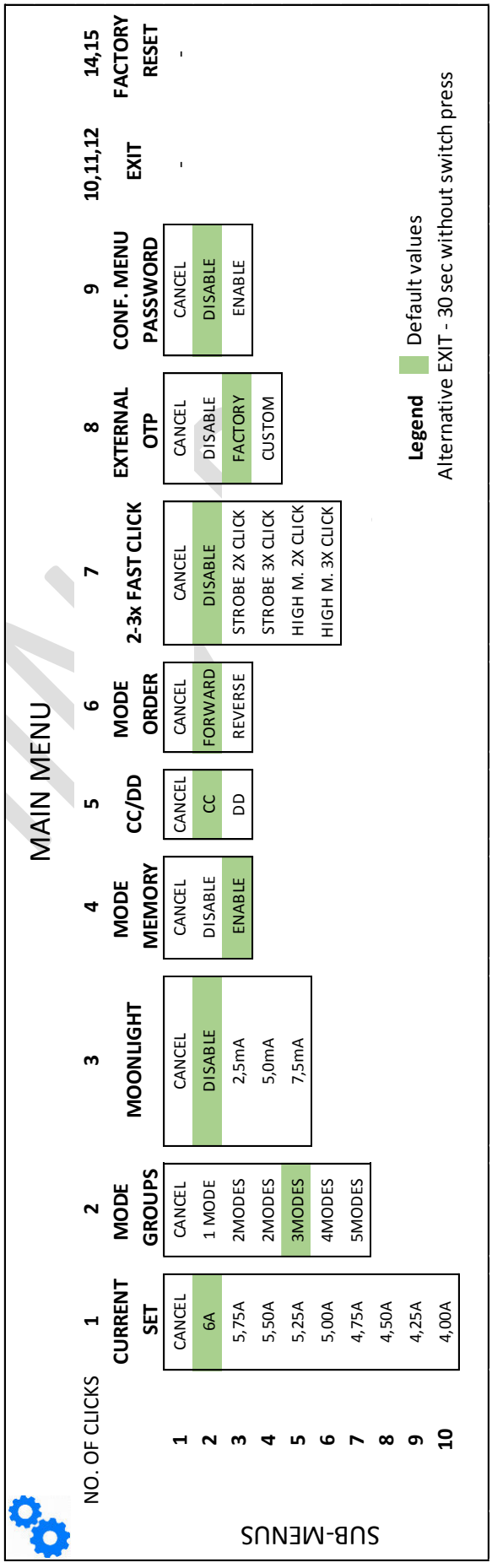
- Driver diameter: 17.00±0.15mm
- Thickness: 2.4±0.15mm
- LED wire pads hole diameter: 1.3mm
- Spring pad diameter: 9.15mm
- Number of el. components on PCB (top side only): 26

Configuration mode

Configuration mode is activated by >10 fast switch presses (half-press) if configuration mode password is disabled (setting No. 9); light with blink fast 5 times as confirmation, and driver will set current to 350mA (Configuration menu level 1) – this means driver is currently in MAIN MENU.
In main menu it's possible to set/change 11 different driver settings, each setting has its own sub-menu:

- 1 – Current on high mode,
- 2 – Mode groups (1 – 5 modes)
- 3 – Moonlight
- 4 – Mode memory
- 5 – Constant current vs. Direct drive on high mode
- 6 – Mode order
- 7 – 2x or 3x fast click special function
- 8 – External OTP sensor threshold
- 9 – Configuration menu password
- 10,11,12 – Configuration menu EXIT
- 14,15 – Factory reset to default settings (green marked fields)

To choose desired sub-menu, fast-click exact number of times according to the table on the right (for example to choose „strobes“ sub-menu, fast-click 7 times).
After that, light will blink the same number of times (7 in case of upper example) and driver will set current to 100mA (Configuration menu level 2) - this current level means driver is currently in SUB-MENU.
Generally, in configuration menu user should always wait until blinks are finished before taking the next step/operation.
Finally, to choose desired setting field, fast-click exact number of times according to table (for example to choose „strobe 3x click“ within „2-3x fast click“, fast-click 4 times).
After that, light will blink the same number of times (4 in case of upper example) and driver goes back to main menu - current will increase to 350mA (Configuration menu level 1) – which is a sign that drives is in MAIN MENU again.
This way it's possible to change all settings without exiting configuration mode by following same procedure described above. By choosing CANCEL field, driver returns back to MAIN MENU.



To exit configuration mode, fast-click 10-12 times while driver is in MAIN MENU – light will blink fast 10 times and then go to sleep (shutdown).
If switch is not pressed for 30 seconds, driver will exit automatically.
Factory reset can be activated by 14-15 fast-clicks while driver is in MAIN MENU – all settings will reset to default factory values (green marked fields).
If configuration menu password is enabled, entering into configuration mode is slightly different:
fast-click >10 times; light with blink 2 times, and driver will set current to 350mA (driver is not in configuration menu yet). User now must enter correct password (1865); this is done by „fast-clicking" one digit at time.
Fast-click 1x – light will blink once as confirmation, next fast-click 8x – light will blink once again; procedure is the same for last two digits.
If password is correct, light will blink fast 5 times, which means configuration mode is active and driver is in MAIN MENU.
If password is wrong, or if user shuts flashlight off during password entering, driver would continue with normal operation.

Note:
In configuration menu, all protections (LVP, ext. OTP, int. OTP) are disabled from practical reasons. This means battery may over-discharge if driver stays in configuration mode for too long!
Also, flashlight and driver might overheat if driver stays too long in EXTERNAL OTP menu – CUSTOM sub-menu

Tip:
If you get lost in (sub)menus, fast-click once – driver will go either to main menu or sub-menu; higher brightness (350mA) current is indicator of main menu, and lower brightness(100mA) is indicator of sub-menu
If brightness lowers, fast-click 1x again to go to main menu

Current set sub-menu

LD-x4 has unique capability of changing current levels down to ~66% via user interface, without any hardware modifications. This can be useful not just for fine-tuning LED current, but for example to reduce current consumption of all modes if longer run-times are needed for some reason.
For 3A driver version it's possible to reduce current down to 2A with 0.125A resolution between steps; for 6A and 9A versions resolution is 0.250A and current can be reduced to 4A and 7A respectively; for 12A version resolution is 0.500A and current can be reduced to 8A.
All modes (except moonlight) are scaled down by same percentage, so overall mode current percentages remain the same.

Note:
Driver will not exit configuration mode by turning flashlight off;
It will stay in conf. mode until user choose exit sub-menu, or if switch is not pressed for 30sec

Note:
Password in not „personal" and cannot be changed; it's purpose is to prevent "uninformed" people to accidentally enter configuration mode and mess-up settings

Note:
(LD-A4 only)
When reducing max. current, it's important to consider possible increase of driver dissipation, because of lager voltage difference between battery and LED. Usually driver will dissipate most heat at medium currents (2-5A with typical CREE leds), because $P_{diss}=\Delta U*I_{led}$ is largest.
Using thermally conductive materials between driver's MOSFET top side and flashlight pill/body would reduce thermal resistance and increase driver's power dissipation capability

CURRENT SET SUB-MENU

NO. OF CLICKS	3Amps	6Amps	9Amps	12Amps
	1	**1**	**1**	**1**
1	CANCEL	CANCEL	CANCEL	CANCEL
2	3A	6A	9A	12A
3	2,875A	5,75A	8,75A	11,5A
4	2,75A	5,50A	8,50A	11,0A
5	2,625A	5,25A	8,25A	10,5A
6	2,50A	5,00A	8,00A	10,0A
7	2,375A	4,75A	7,75A	9,5A
8	2,25A	4,50A	7,50A	9,0A
9	2,125A	4,25A	7,25A	8,5A
10	2,00A	4,00A	7,00A	8,0A

Mode groups sub-menu

In mode groups sub-menu, there are 6 different mode groups, from single 100% mode only, to up to 5 modes. Percent values in table below are current percentages (highest mode is always 100%).
Together with current set, mode memory, CC/DD and mode order settings, it's possible to create a large number of various UIs.
Moonlight mode is separate additional low current mode that can be added to any mode group.

MODE GROUPS SUB-MENU

NO. OF CLICKS	2
1	CANCEL
2	100%
3	9% - 100%
4	16% - 100%
5	2,5% - 20% - 100%
6	2% - 10% - 30% - 100%
7	1,5% - 7% - 18% - 35% - 100%

Moonlight sub-menu

In moonlight sub-menu, it's possible to enable or disable moonlight mode, and choose between three different moonlight current levels: 2.5mA, 5.0mA and 7.5mA (@4.2V cell voltage).
Unlike LD-2/3, no additional parts are needed for moonlight mode.
Because current in moonlight mode is resistor limited, it linearly depends on battery voltage, so current will drop as battery voltage drops. This is usually a desirable effect, since it enables longer run-times with gradually reduced light output.

Run-times on lower modes

When LED currents are low, driver's active state current consumption has significant effect on total run-time.
Run-time for any driver on low modes can be calculated according to the equation on the right side.
LD-x4 has relatively low active state current consumption, about 1.6mA without bleeding, and only 2.6mA with low current bleeding(for illuminated tailcap support); for comparison, traditional resistor bleeding method consumes 5-10 times more (470 Ohm resistor consumes ~9mA with fresh cell). High bleeding current reduces run-time and lamp lm/W on moonlight mode dramatically. For example, same LD-x4 with 470 Ohm resistor bleeder would have total active state current consumption of 10.5mA vs 2.6mA with low current bleeding. Run-time on 2.5mA moonlight mode is at least 2.5 times better with low current bleeding vs resistor bleeding.

Run-time on low modes for any driver can be calculated as:

$$T_{run}\,[\mathrm{h}] = \frac{C_{batt}[mAh]}{I_{led}[\mathrm{mA}] + I_{drv}[\mathrm{mA}]}$$

where:

C_{batt} – battery capacity [mAh]
I_{led} – LED current [mA]
I_{drv} – active state driver consumption

Constant current/Direct drive (CC/DD) sub-menu

One more unique feature of LD-x4 is capability to choose between current regulated or "direct-driven" high mode.
Driving newest LEDs at maximum possible currents is a popular way to get maximum brightness from smallest package. Because of high forward voltages of 2nd generation CREE LEDs, maximum attainable current from Li-ion batteries in combination with linear or DD drivers is usually lower than LED "fusing" current.
If maximum current is needed, user can enable DD setting field. Thanks to LD-x4's exceptionally low internal resistance (5mΩ), there will be practically no difference in output current compared to high quality DD drivers with big low resistance MOSFETs.
All other modes except high mode will remain CC regulated, which gives best possible lm/W from LEDs.
LD-x4 drivers have "hardware" supported direct-drive, this means there are no limitations on DD current like on LD-3 drivers.
One advantage of DD mode is very low power dissipation in driver on DD mode, so there is usually no need to improve thermal path between driver and flashlight pill/body.
On the other side, some LEDs are more sensitive to overdriving or have low forward voltage, so current limiting on high mode may be desirable.
If LED's V_f is low enough, current limiting also offers more predictable run-time, brightness, and power dissipation. In those cases CC mode may be more suitable.
Because all newer generation of LEDs from various manufacturers have very low forward voltage, current limitation if often only thing that would prevent LED from failure. In these cases DD mode would be a very bad choice, and even if LED doesn't fail immediately, it would have very poor lm/W ratio and significantly reduced life span.
Since LD-x4 is linear type of driver, it will convert excess voltage into heat, and at medium-high currents LD-A4 driver needs good thermal path to stay within max. operating temperature range.
LD-B4 doesn't have these problems because MOSFET which generates heat can be placed on MOSLED metal core PCB together with LEDs and NTC temp. sensor. This way MOSFET has very good thermal path to flashlight body, and it can dissipate a lot of heat/power without overheating. Except LED wires, only one additional thin wire (Gate control) is needed for proper operation of LD-B4 – MOSLED setup.

Note:
There will be no difference between CC/DD mode if LED forward voltage is high enough to prevent linear driver from regulating current; linear drivers can't regulate current if LED voltage needs to be bigger than battery voltage at that current

2x-3x fast click sub-menu

In 2x-3x fast click sub-menu, it's possible to choose which special function will be active when user fast-clicks two or three times in a row during normal operation. There are two possible special functions:

- Tactical strobe – 12,5Hz frequency
- High mode

There is also an option to choose number of fast-clicks to activate those two functions. With 2 clicks, desired function can be activated faster, but there is a greater chance of accidental (unwanted) mode activations; 3x click option reduces that chance at cost of longer time needed to activate function.
Strobe function is deactivated with single switch click (mode change or turn-off).

External OTP sub-menu

In this sub-menu user can configure temperature threshold level of external over – temperature protection, or completely disable it.
Default factory value is ~65°C, but that can be changed to custom level by choosing setting field "CUSTOM".
To set custom OTP threshold user should first "preheat" flashlight in normal mode. This is needed because of 30sec no-press shut-down in configuration mode, which would become active (in most cases) before flashlight reaches desired temperature if flashlight is not close to desired OTP threshold before that. After flashlight reaches temperature close to desired OTP threshold, user should enter into configuration menu and choose CUSTOM field under EXTERNAL OTP sub-menu.
After activating CUSTOM setting field, driver will set current to max. (100% or DD, depending on CC/DD setting). User should wait until flashlight body reaches desired temperature (this time must be less than 30sec!), and then turn-off (full click) and turn-on flashlight again. On next turn-on, driver will store current flashlight temperature as new threshold. Because flashlight is still at basically the same temperature, external OTP will usually become active and reduce output current – turn the light off for 1 – 2 min to allow flashlight to cool down.

Note:
For proper external OTP operation, NTC resistor (100kOhm, B=4250K) should be mounted inside of flashlight, and connected to driver
MOSLED MCPCB has NTC footprint on board, so it is the easiest method for NTC mounting and connecting

Note:
If there is no NTC connected, ext. OTP won't work, but all other driver functions would work normally

Low voltage protection – LVP

LD-x4 has 2 step voltage protection based on accurate calibrated internal voltage reference. When battery voltage drops below 3.0V, light will blink 5 times and LVP step 1 becomes active. Driver will reduce/limit current to 3% of max. current if current mode level is higher than 3%. Modes lower than 3% would work as usual.
When battery voltage drops below 2.8V (LVP step 2), light blinks 10 times and driver goes into shutdown/sleep mode.

Internal and external overtemperature protections - OTP

LD-x4 has two OTP protections: internal and external.
Internal OTP uses microcontroller internal temp. sensor which monitors driver's PCB temperature; if PCB temperature becomes higher than predefined threshold (~105°C), light will blink fast 15 times and driver will shut down completely to prevent circuit damage. Role of internal OTP is to protect driver from fault conditions, such as too high power dissipation caused by improper choice of LEDs/batteries combination, or not good enough thermal path.
Internal OTP is always active (except in configuration mode) and cannot be disabled.
Obviously, internal OTP protection is not needed for LD-B4 because driver board would never be hot enough, but it's still implemented as additional safety measure.

External OTP uses external NTC sense resistor for measuring real flashlight body temperature. When flashlight body temperature becomes higher than ext. OTP threshold level, light will blink fast two times and driver will first change mode to previous, and then further reduce current if temperature is still higher than threshold. When temperature drops below threshold, current will start to increase, until it reaches previous mode current level.
External OTP threshold level can be set in external OTP sub-menu when driver is in configuration mode (see "External OTP sub-menu" section for details).

External vs. internal temperature sensor for measuring flashlight temperature

There are several reasons why monitoring flashlight body temperature with external sensor is required for accurate results:

- external sensor can be mounted very close to source of heat (LED) – this minimizes thermal resistance path between sensor and heat source, and ensures fast response; on the other side thermal resistance between internal sensor (that is inside of uC package) and flashlight body is large because of plastic uC package and additional large thermal resistance between uC and flashlight body/pill
- ext. sensor has much smaller mass compared to bigger microcontroller package (SOIC, DFN, etc.) – smaller mass gives smaller thermal capacitance, which gives faster response; on the other side uC package is bigger, which together with large thermal resistance causes large $R_{th}C_{th}$ thermal constant, and large RC constant causes slow response time

- last but most important: because there is no 100% efficient driver, every LED driver generates heat. Since microcontroller is usually on the same PCB close to power dissipating components, its internal sensor would sense driver PCB temperature, and if any of the surrounding components dissipate heat (like MOSFET and 7135 ICs in linear/DD drivers), driver PCB temperature could be significantly hotter than actual flashlight body temperature. This will cause false over – temperature triggering which cannot be corrected in firmware since there are too many unknown parameters.

Thermal path considerations

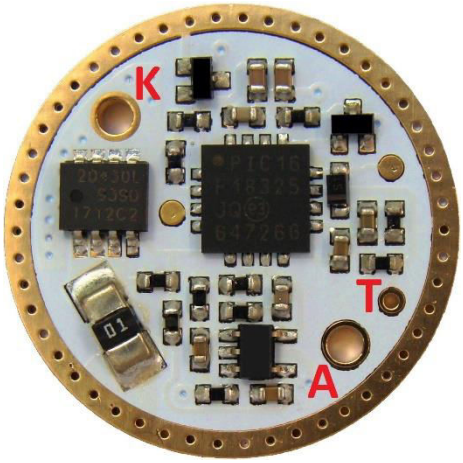
LD-x4 is linear type of driver, which means it "burns" extra voltage from battery to limit LED current. Result is heat that is generated mostly in MOSFET, and equation for generated heat in driver is:

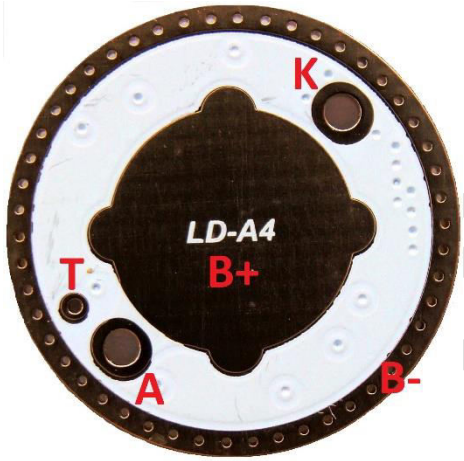
$P_{heat}=(V_{BATT} - V_{LED})*I_{LED}$

So, larger voltage difference between battery and LED, and LED current would result in bigger power dissipation in driver.
How much power driver can dissipate, depends mostly on how good is MOSFET thermally connected with flashlight body.
LD-B4 uses external MOSFET which can be placed on MOSLED or MOSLED EXTREME PCB, so thermal transfer in that case is very good, and MOSFET can handle ~15Watts of heat – more than any typical 1S setup (1-4 LEDs in parallel) would generate. This makes LD-B4 a preferable choice in high power LED setups.
LD-A4 has standard design with MOSFET on driver's PCB, so thermal transfer in typical LED flashlight hosts with large air cavities/pockets is not nearly as good. Drivers' thermal resistance in a typical flashlight pill without any improvements is ~21°C/W, so max. power dissipation is ~3.8W@25C, and ~2.1W@60C.
To improve thermal transfer, air should be replaced with material with higher thermal conductivity – the higher, the better.
One simple method is to use cheap thermally conductive silicone pieces (~1W/mK) and tightly fill driver cavity with it.
Measurements show that this decreases thermal resistance to ~15,5°C/W, so max. power dissipation is now ~5.1W@25C, and ~2.9W@60C.
Even better results are accomplished with "sandwich" made of 2 pieces 0.5mm 3,5W/mK thermal silicone sheets with aluminum piece/rod in between, with total thickness such that it tightly fits in pill.
Thermal resistance in that case is reduced to ~11°C/W, and max. power dissipation increases to ~7.3W@25C, and ~4.1W@60C.
By using more expensive 0.5mm silicone sheets with 6W/mK instead of 3,5W/mK, thermal resistance is further reduced to only ~8°C/W, which means max. power dissipation in that this case is 10.0W@25C, and 5,6W@60C.

Connection diagram

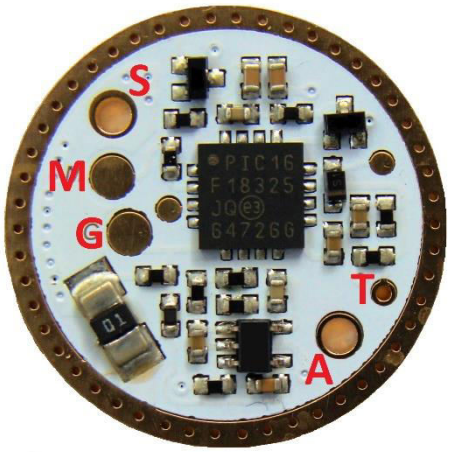
LD-A4

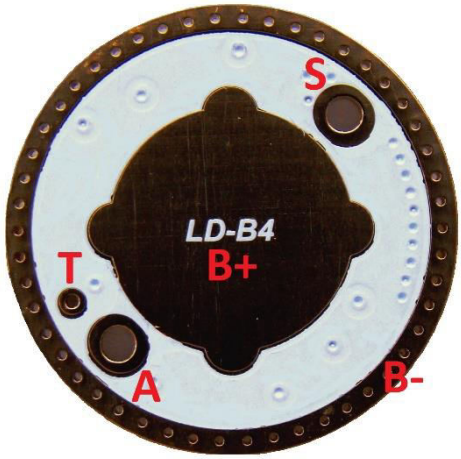




Required connections for basic operation: A,K,B+,B-

LD-B4





Required connections for basic operation: A,K,G,B+,B-

Contacts description

"A" - to LED anode("+" on MOSLED or MOSLED EXTREME MCPCB)
"K" - to LED cathode
"T" - to NTC temp. sensor ("T" on MOSLED or MOSLED EXTREME MCPCB)
"S" - to external MOSFET Source pin ("–" on MOSLED or MOSLED EXTREME MCPCB)
"G" - to external MOSFET Gate pin ("G" on MOSLED or MOSLED EXTREME MCPCB)
"M" - to LED cathode ("M" on MOSLED or MOSLED EXTREME MCPCB) - required for moonlight mode on LD-B4
"B+"- to Battery plus
"B-"- to Battery minus