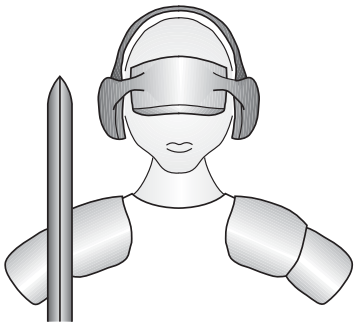
LED-Warrior04

Intelligent 4 channel LED driver with bus interfaces



Code Mercenaries

1. Features

- Four channel high power LED driver
- Input voltage 7 - 32 V DC
- Constant current output 80 mA to 1000 mA
- Current programmable per channel, 5 mA steps
- Internal 12 bit PWM dimming for each channel
- Extreme dimming range down to 0.024%
- Flicker free spread spectrum PWM dimming
- Maximum output power: 25 W per channel
- Up to 94% efficiency
- Negligible output ripple current
- I2C control and programming interface
- DMX512 control
- IWC62386 (DALI*) (bus interface on piggyback module)
- Tunable White mode for IEC62386
- Wireless add on module (compatible to BT 4.0)
- Autonomous operation, configurable via I2C
- Programmable dynamic light scenarios

2. Functional overview

LED-Warrior04 is a point-of-load constant current DC/DC regulator for LED lighting applications. It offers multiple options for lighting control. Direct control of the four channels via I2C, IEC62386, DMX512, or wireless is possible as well as autonomous operation with settings preprogrammed via I2C, including dynamic light scenarios.

2.1 Flicker free dimming

LED-Warrior04 uses a very sophisticated dimming method. PWM is often criticized for generating flicker and interference with cameras or other dimmed light sources.
The spread spectrum dimming used in LED-Wariror04 avoids these problems. Instead of running at a fixed frequency the spread spectrum dimming varies the PWM frequency in a pseudo random pattern. This method is also used by modern wireless communication to avoid interference.
In LED-Warrior04 the spread spectrum dimming varies between 182 Hz and 187500 Hz. The actual bandwidth depends on the dimming level. At levels close to 0% or 100% the bandwidth and frequency are lower.
This ongoing variation of the PWM frequency eliminates any perceptible flicker and most interference with other light sources or cameras.

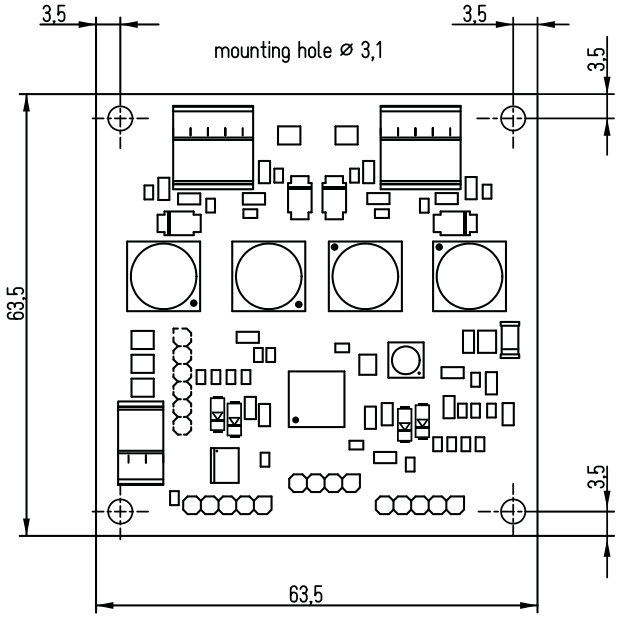
2.2 No artifacts from DC/DC

Ripple from DC/DC converters is a concern for high quality lighting. LED-Warrior04 runs at very high switching frequencies to eliminate ripple.
Depending on current settings and the ratio of input to output voltage the switching frequency varies between about 400 kHz and 2 MHz.
This puts LED-Warrior04 in a different league compared to most LED drivers.

2.3 Detailed control

Each of the four channels can be individually programmed for a LED current between 80 mA and 1000 mA in steps of 5 mA (184 steps total). In addition the 12 bit PWM for each channel allows to set 4096 different brightness levels independent of the current.
This results in >750000 combinations of current and PWM for each channel.

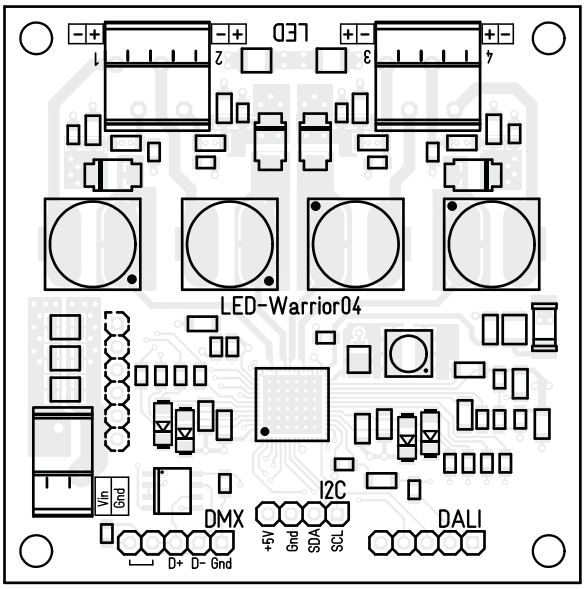
3. Mechanical dimensions



Dimensions in mm
Height at thickest point: 16.3 mm
Outer contour tolerance: ±0.2 mm

LED-Warrior04

3.1 Pin Description



Vin
Supply voltage input. Apply a DC voltage of 7V to 32V here.

GND
Ground reference.

DMX+/DMX-
RS485 DMX port, connect direct to the DMX bus. Close jumper for bus termination.

I2C
SDA, SCL lines of the I2C interface. Use only SDA, SCL and Gnd to connect to any self supplied controller or computer.
+5V is a power output from LED-Warrior04 that is generated from Vin. +5V can supply power to add on modules like the wireless module. Do not connect an external power supply here!

DALI (*)
The IEC62386 (DALI*) physical bus interface module can be placed on this header

Ch1, Ch2, Ch3, Ch4
Outputs to the LED strings. The negative pins are not identical with ground. The positive outputs are not identical to supply power.
LED strings have to be connected between the two pins on one channel.

4. Connecting the LEDs

The maximum number of LEDs that can be driven by LED-Warrior04 depends on the supply voltage and the combined forward voltage of the LEDs.
Input voltage needs to be about 2.5V higher than the total forward voltage of the LED string for proper operation.
Connect the LED strings between the + and - outputs for each channel.
A LED string has to be connected to both pins of one output!
Do not connect one end of the LED string to supply power or ground!
Do not connect pins of two outputs together!
Do not cross connect LED strings between the pins of different outputs!
Any configuration where one end of the LED strings is connected to a common pin does not work!

4.1 EMC

LED-Warrior04 has been designed to produce a minimal level of RF emissions.
As a component LED-Warrior04 can not be EMC approved but the EMC tests in a typical configuration were completely unproblematic. Test results are available on request.
The utilization of the spread spectrum PWM for dimming does reduce RF missions generated by LED-Warrior04.

4.2 Output ripple

Current ripple on the LED-Warrior04 outputs is in a very high frequency range due to the fast switching speed of the DC/DC conversion. The actual ripple current is negligible and in most cases complicated to measure due to its small amount and high frequency.

5. Controlling the LW04

LED-Warrior04 is designed to be controlled via I2C, DMX-512, or IEC62386 (DALI*). It can also be programmed for autonomous sequence operation.

5.1 I2C control

The primary configuration and control interface for the LED-Warrior04 is the I2C interface. It allows to set all parameters of the LW04, change the DMX address, set channel currents for IEC62386 mode, and to program it for autonomous operation.

5.1.1 I2C addressing

The factory default I2C address is $07 (7 bit format, to be shifted up one bit to add R/W bit)
The LED-Warrior04 I2C address can be programmed to any valid I2C address by sending a broadcast command (address 0) followed by the register number $04 and the new I2C address.
To change the address LED-Warrior04 has to be the only device connected to the I2C.

5.1.2 I2C registers

I2C communication with the LED-Warrior04 is done via registers. The first byte of a write transaction contains the register number.
A read transaction always reads from the last accessed register. Reading multiple registers in a single transaction is possible by reading the appropriate number of bytes (i.e. reading 4 bytes starting with register 2 returns the currents for all four channels).
The register address is not changed by a read command, i.e. if the last register accessed was number 6 any subsequent read access will start at register 6 until the register number is changed by a write transaction.

Reg#	Bytes	R/W	Description
1	9	R	Device Descriptor
2	1	R/W	Current Channel 1
3	1	R/W	Current Channel 2
4	1	R/W	Current Channel 3
5	1	R/W	Current Channel 4
6	2	R/W	PWM Channel 1 (12 bit)
7	2	R/W	PWM Channel 2 (12 bit)
8	2	R/W	PWM Channel 3 (12 bit)
9	2	R/W	PWM Channel 4 (12 bit)
10	1	R	not used (removed in V1.1)
11	1	R/W	Controller Mode 1
12	1	R/W	Controller Mode 2
13	2	R/W	DMX512 Start Slot
14	1	W	Flash Write / Reset
15	2 / 9	R/W	Sequence Mode Table
17	1	R/W	Extended mode

All multi byte registers are in little endian format (first byte contains least significant bits).

5.1.3 Register 1: Device Descriptor (read only)

Byte 1: Length Byte
Length of register 1 including the length byte itself. (Future versions may append additional data)
Byte 2-5: Serial Number
A unique 32-bit serial number, factory programmed, LSB first
Byte 6-7: Version
The 16-bit value is composed of the following halfbytes (LSB first):
<Major-Version>.<Minor-Version>.<Major-Release>.<Minor-Release>
Byte 8-9: Model
$0004 for standard LED-Warrior04, LSB first.

5.1.4 Register 2 - 5: Channel X Current

The average output current for channel 1/2/3/4 in milliampere divided by five (i.e. decimal 100 equals 500 mA drive current). Values from 16 to 200 are valid. Out of range values will be clipped.
Writing to the channel current registers must be enabled by setting the enable bit in register 11. Any write to registers 2-5 are ignored unless bit 7 in register 11 has been set.

5.1.5 Register 6 - 9: Channel X PWM

A 12-bit little endian value to fade channel 1/2/3/4. Changes to these registers will only take effect if I2C is set as dimming input in controller mode 0 register (register 11). LSB first

5.1.6 Register 10: LED Status (removed)

Register function has been removed with chip revision V1.1 since it did not provide consistent results.

5.1.7 Register 11: Controller Mode 1
Bit 0 - Activate channel 1 driver (1 = active)
Bit 1 - Activate channel 2 driver (1 = active)
Bit 2 - Activate channel 3 driver (1 = active)
Bit 3 - Activate channel 4 driver (1 = active)
Bit 4 - Dimming source 0
Bit 5 - Dimming source 1
Bit 6 - Activate sync mode
Bit 7 - Enable current setting

Dimming source selects which bus is active or if an autonomous sequence controls the channels:
0b00 - I2C
0b01 - DMX512
0b10 - IEC62386
0b11 - Sequence Mode
Activate sync mode selects synchronized dimming mode when set to 1. If sync mode is enabled any values written to registers 6…9 are not used until receiving a broadcast $0A I2C command. This allows to switch multiple LED-Warrior04 to new brightness values simultaneously to avoid a wave effect that would occur with sequential writing.
Enable current setting has to be set to "1" prior to any writes to registers 2-5. This is intended to prevent accidentally setting current values that may damage the connected LEDs. Writing to any other register than a channel current register does reset this bit.

5.1.8 Register 12: Controller Mode 2
Bit 0 - unused, always write as 0
Bit 1 - unused, always write as 0
Bit 2 - unused, always write as 0
Bit 3 - unused, always write as 0
Bit 4 - unused, always write as 0
Bit 5 - Sequence write, enables writing register 15
Bit 6 - DMX linear (1 = disable logarithmic curve)
Bit 7 - unused, always write as 0

Sequence write has to be set to enable writing a new sequence table via register 15. Writing to any other register than 12 or 15 resets this bit. Completing the write of a sequence table also resets this bit.
DMX linear allows to disable the default logarithmic mapping of DMX 8 bit dimming value to 12 bit PWM values. If this bit is set the DMX values will be multiplied by 16 to generate the PWM values. Default is that the DMX values are mapped via a logarithmic table to get a human perception optimized dimming curve.
Bit 7 was removed in V1.1.0.0.

5.1.9 Register 13: DMX512 Start Slot
This 9-bit little endian value is used as the first slot number of four consecutive DMX slots which set the PWM channels if DMX512 is set as dimming input in register 11 (Controller Mode 0)

5.1.10 Register 14: Flash Write (write only)
Register 14 allows to write the current settings to the flash memory. On the next power up reset the settings will be retrieved from flash memory and used as default.
Bit 0 - unused, always write as 0
Bit 1 - Store IEC62386 modes in flash
Bit 2 - Store sequence table in flash
Bit 3 - Store DMX start slot number in flash
Bit 4 - Store controller mode in flash
Bit 5 - Store PWM values in flash
Bit 6 - Store current values in flash
Bit 7 - Restore values from flash

Writing any of the bits as "1" does cause the corresponding currently active parameters to be written to flash memory.
Writing $80 to this register performs a soft reset. All controller variables are set to the values stored in flash memory.
This command resets the LED-Warrior04 to the same status as a power up does, it can not be combined with any write commands.

5.1.11 Register 15: Sequence table writing
Sequence mode allows the LED-Warrior04 to autonomously perform dynamic lighting scenarios. This can be used to generate a power on fading, continous changing light situations, flashing, color changing, or any other lighting applications where a dynamic lighting without a external controller is required.
Sequence mode is controlled by a table containing time and PWM values. The table is specified in 5.2.
Before writing to register 15 it has to be enabled by setting bit 5 of register 12 to "1". The write bit is automatically reset when the table has been written completely or an error condition occured.
Each write transaction to register 15 can contain 1 to 9 data bytes. Write transactions automatically go to ascending table positions until an error condition is detected, or the table is complete.
Reading from register 15 returns a two byte status for the sequence table. If the table has been written successfully the first byte contains the number of bytes written and the second holds a checksum generated by xoring all table bytes.
In case of an error the first byte is set to zero and

the second byte contains the error code:
$01 - Write bit has been reset before a complete table header was transmitted
$02 - Write bit has been reset before a complete table (number of data sets according to table header) was transmitted
$04 - More data sets than specified in the table header have been written
$08 - Write access to other registers terminated the table writing
$10 - Write attempt to register 15 without write enable bit being set.
$20 - Length data in table header specify too many data sets (>81).

5.1.12 Register 17: Extended mode
This register and the associated modes have been introduced with LED-Warriro04 V1.1.0.0
The added capabilites allow a Tunable White mode for IEC62386 and can restrict the number of channels used for IEC62386 and DMX to reduce address space usage if fewer than all four channels are required.
This is the format of the one byte register:
Bit 0 - channels LSB
Bit 1 - channels
Bit 2 - channels MSB
Bit 3 - unused, write 0
Bit 4 - unused, write 0
Bit 5 - unused, write 0
Bit 6 - Twin mode
Bit 7 - Tunable White mode

channels is a three bit value setting the number of active channels to be used for IEC62386 and DMX. Valid values are 1, 2, 3, 4. Factory default setting is 4 to use all channels. By reducing the number of active channels the addresses required by one LW04 are reduced. If short addresses are assigned to IEC62386 channels and the number of channels is reduced then the short address for the then unused channels will be cleared.
Twin mode is applicable for IEC62386 only and may be set only when Tunable White mode is selected and channels is set to 2. If Twin mode is selected LW04 will drive the channel pairs 1 & 2 and 3 & 4 with identical values.
Tunable White mode is applicable for IEC62386 only. If selected it will run the channels 1 & 2 and 3 & 4 as paires to drive tunable white LED setups. See chapter 5.5 for details.
Tunable White can only be selected if 4 channels are active or in combination with Twin mode if 2 channels are selected.

5.1.13 Broadcast commands
LED-Warrior04 implements three I2C broadcast commands. Broadcast commands are write only and are send to address 0.
$04 followed by one data byte sets the I2C address of the LED-Wariror04 to the data byte as the new I2C address, values 1…127 are valid.
$0A triggers the activation of new brightness values for all LED-Warrior04 in sync mode (set in register 11).
$0B followed by one data byte sets the dimming source on all connected LED-Warrior04 simultaneously. This is useful to synchronously start sequence mode on several LED-Warrior04.
The data byte has only two active bits:
Bit 0 - unused, write 0
Bit 1 - unused, write 0
Bit 2 - unused, write 0
Bit 3 - unused, write 0
Bit 4 - Dimming source 0
Bit 5 - Dimming source 1
Bit 6 - unused, write 0
Bit 7 - unused, write 0

Dimming source selects which bus is active or if an autonomous sequence controls the channels:
0b00 - I2C
0b01 - DMX512
0b10 - IEC62386
0b11 - Sequence Mode

5.2 Sequence mode control
If sequence mode is enabled as the active dimming source and a valid sequence table has been loaded LED-Warrior04 will work autonomously executing the sequence table.
The sequence table is made up of the table header and up to 81 data sets.
The table header contains the following 10 bytes:
Byte 0 - Sync 1/2
Byte 1 - Sync 3/4
Byte 2 - Repeat 1
Byte 3 - Repeat 2
Byte 4 - Repeat 3
Byte 5 - Repeat 4
Byte 6 - Length 1
Byte 7 - Length 2
Byte 8 - Length 3
Byte 9 - Length 4

Sync contains the flags for each channel to synchronize with other channels. Sync 1/2 contains the sync bits for channel 1 in the lower half byte and for channel 2 in the upper half byte. Sync 2/3 contains the sync bits for channels 3 and 4.

If a sync bit is set the channel waits for the corresponding channel to come to the end of its sequence instance before it continues with the next iteration of its own sequence.
I.e. if Sync1/2 is $04 then channel 1 will wait for channel 3 to reach the end of its sequence iteration before it starts its own next iteration. If channel 3 had already reached its sequence iteration end then channel 1 will continue immediately. Setting Sync1/2 to $12 will cause channels 1 and 2 to wait for each other at the end of their sequence iteration to continue together.

Repeat contains the number of iterations for the sequence for the corresponding channel. $00 means the sequence will repeat infinitely.

Length sets the number of data sets for each channel. Data sets are stored consecutively in the table, starting with those for channel 1. If there are 0 data sets for a channel it takes up no space in the table.

Data sets contain three bytes each:
Byte 0 - PWM LSB
Byte 1 - Time LSB
Byte 2 - PWM/Time MSB

Byte 2 contains a half byte MSB for Time in its lower half byte and a half byte MSB for PWM in its upper half byte to get a total 12 bit value for each PWM and Time.
PWM is the brightness value that should be reached and Time the time to transition from the currently active value to that target value in 10 ms steps. The maximum transition time in one data set is 40.95 sec. A time value of 0 is invalid and automatically corrected to 1. Transition between the values is linear.
For longer transition times or non linear behaviour multiple data sets may be used.

5.3 DMX512 control

Since DMX512 is a simple lighting protocol it allows only to set the brightness (PWM) values of the output channels.
The starting slot number for DMX512 can be set via I2C. Four consecutive slots are used to control the brightness of the four channels, unless the number of channels is reduced via register 17. In this case only the number of active channels will use the data slots.
To use DMX512 it must be set as the dimming source in I2C register 11.

5.4 IEC62386 control

LED-Warrior04 implements the IEC62386 protocol according to DIN EN62386-102 and DIN EN 62386-207, as required for control gear for LED.
LED-Warrior04 shows up on the IEC62386 bus as four separate devices.
To use IEC62386 it must be set as the dimming source in I2C register 11.

5.5 Tunable White mode

Starting with V1.1.0.0 LED-Warrior04 supports a tunable white mode when controlled via IEC62386. The tunable white function is enabled via Register 17 (chapter 5.1.12).
The tunable white mode is intended to offer a simpler method than IEC62386 DeviceType 8.
In tunable white mode channels 1 & 2 and 3 & 4 are run as pairs. The cold white LEDs should be connected to the channels 1 and 3, the warm white to channels 2 and 4.
The IEC62386 addresses normally used by channels 1 and 3 will now control the brightness of the respective channel pair while the addresses used by channels 2 and 4 will control the color mix.
This allows to control tunable white luminaires with simple dimmers.
To run both channel pairs with the same values the Twin mode can be used. This reduces the required IEC62386 addresses to two.

6. Regulator efficiency

The regulator efficiency depends on a number of parameters. Since there are a couple constant losses independent of the total power delivered by the regulator the basic rule is that the regulator is more efficient when used at higher power (i.e. more LEDs connected). A lower difference between input and output voltage does also increase the efficiency.

6.1 Output current

Maximum output current per channel is 1 A.
The actual output current deviates a bit from the programmed value. The amount of current error depends on the ration of input to output voltage and the current setting.

6.2 Reliability

LED-Warrior04 contains no aging components except the Flash memory. Life expectancy is well above 100000 hours.

7. FCC / CE

The LED-Warrior04 is sold as a module to be integrated into a device. As such it can not be FCC or CE approved.

Code Mercenaries has excerted greatest care in designing this module to minimize RF emission and assure safe and stable operation. Though the use of proper cable materials and correct integration into a device is crucial to assure product safety and interference free operation. The integrator who assembles the module into a device has to take care for appropriate construction and testing.

LED-Warrior04 has been EMC tested in a typical configuration and found to be well within the limits of CE and FCC. Test documentation is available on demand.

8. Absolute maximum ratings

Input Voltage (Vin relative to GND):	0 V to 36 V
Input Current:	4.5 A (average)
SDA, SCL pin input voltage (relative to GND):	-0.3 V to 5.5 V
DMX pin input voltage (relative to GND):	-10 V to 15 V
Storage temperature:	-55°C to +115°C
Ambient temperature with power applied (no output driven):	-40°C to +85°C
ESD:	2000 V (human body model)

Absolute maximum ratings must not be exceeded or permanent damage to the LED-Warrior04 may result.

8.1. Operating conditions

	Parameter	Min	Typ	Max	Unit	Remarks
V_{in}	Operating Voltage	7		32	V	
I_{in}	Operating Supply Current			4500	mA	
t_{op}	Operating temperature	-10		60	°C	in still air
I_{idle}	Idle mode current		15		mA	V_{in} =24 V, all channels off
V_{i2c}	Voltage on I2C pins	0		5	V	relative to GND
V_{DMX}	Voltage on DMX pins	-7		12	V	
R_{DMX}	Termination resistor on DMX		120		Ω	enabled by jumper
I_{aux}	Available current on I2C connector			30	mA	Vout = 5 V
V_{out}	Output voltage on each channel			V_{in} -2.5	V	varies with LEDs
I_{out}	Output current on each channel	80		1000	mA	programmable
I_{outerr}	Output current error		±20	±40	mA	deviation from set value
P_{out}	Output power for each channel			25	W	independent for each channel
P_{idle}	Idle power consumption	250		400	mW	all channels off, no bus traffic

8.2 Thermal precautions

When operating at elevated ambient temperature, vertical mounting in an air volume sufficiently large to allow convection is recommended to reduce surface temperature of the regulator. Additional cooling measures can help to further reduce the regulator temperature and increase long term reliability.
No part of the module surface may exceed 95°C during operation.

8.3 Failure modes

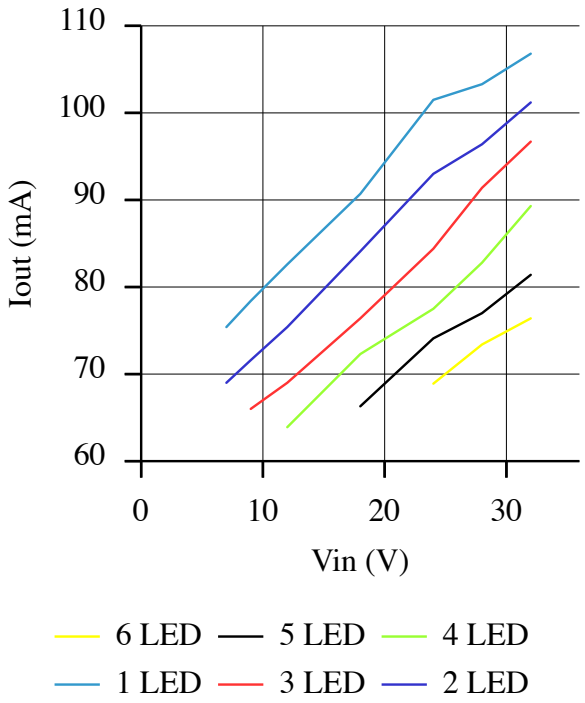
The most common failure mode seen when the LED-Warrior04 is destroyed due to a departure from maximum operating conditions is that it goes into an inert status. Though it is not impossible that a failure can lead to an internal short circuit.

8.4 Recommended safety measures

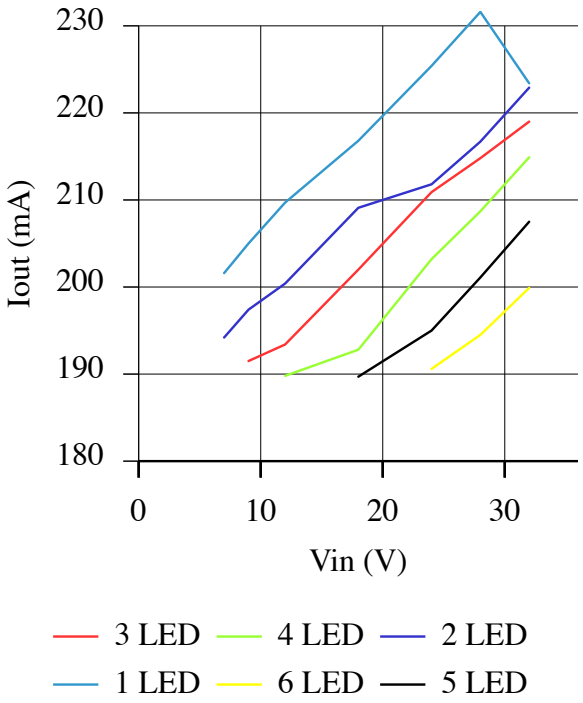
Failure current limiting by a fuse dimensioned for the application or by a power source that is current limited is recommended.

8.5 Output current accuracy

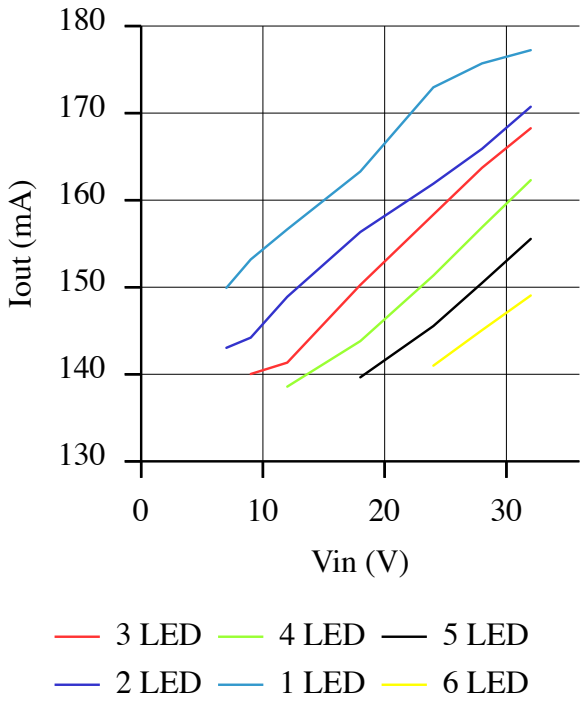
Iout @ 80 mA setting



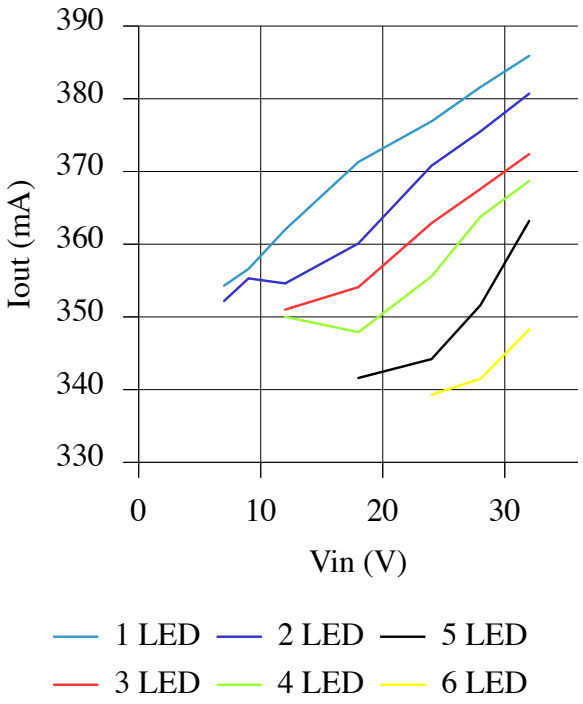
Iout @ 200 mA setting



Iout @ 150 mA setting



Iout @ 350 mA setting



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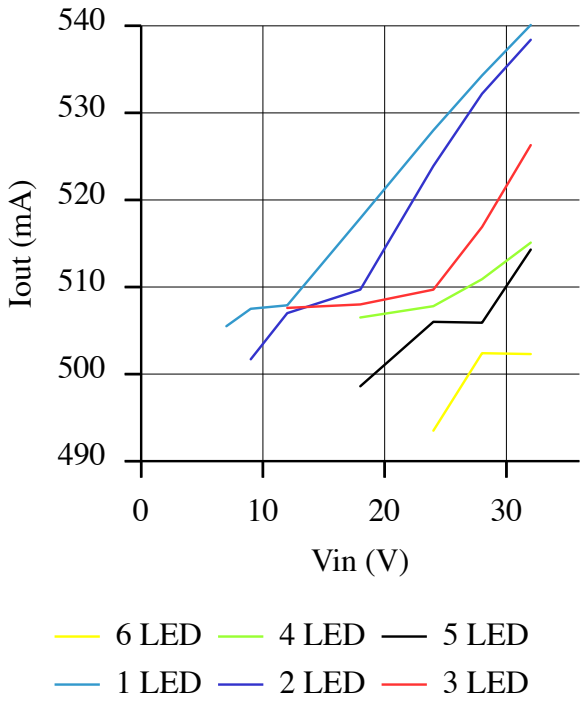
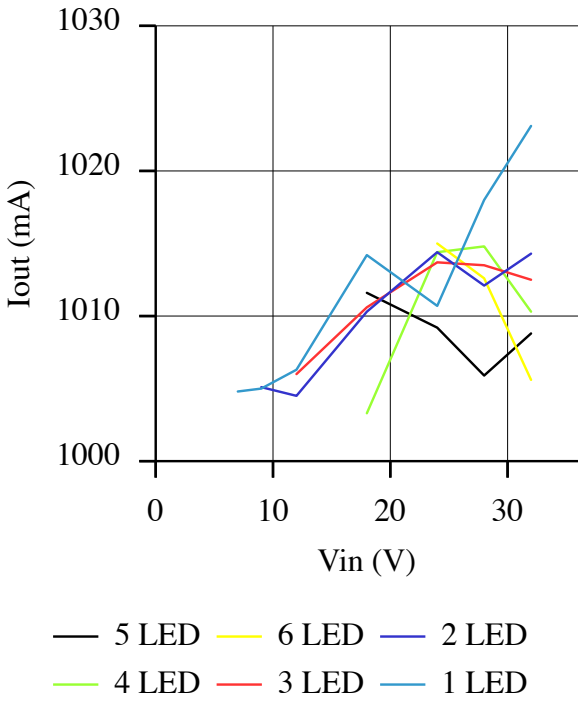
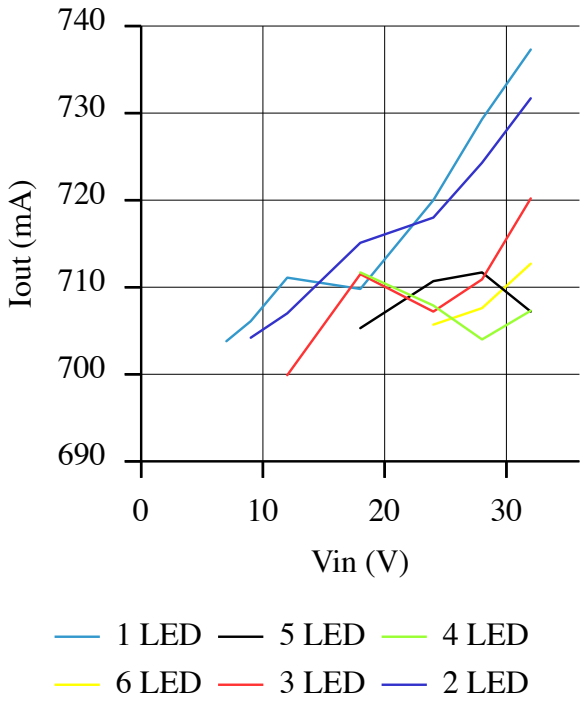
Iout @ 500 mA setting



Iout @ 1000 mA setting



Iout @ 700 mA setting



The above diagrams show typical output currents with strings of white LEDs. Actualy values can vary somewhat depending on the properties of the LEDs and should be tested for the specific application.
Primary purpose of these diagrams is to show that the current error is relatively small with typ. < 2% at 1000 mA.

9. Ordering information

Partname	Order Code	Description
LED-Warrior04	LW04-MOD	1A intelligent 4 channel LED driver
LED-Warrior04 IEC62386 Module	LW04DI-MOD	Bus driver module for IEC62386 connection of LW04
LED-Warrior04 Wireless Module	LW04BT-MOD	Wireless add on module for LED-Warrior04
LED-Warrior04 Starterkit	LW04KIT	Starterkit with USB to I2C interface, LW04 and LW04DI-MOD
LED-Warrior04 Starterkit wireless	LW04KITBT	USB to I2C interface, LW04, LW04DI-MOD, LW04BT-MOD

The modules listed here are standard products. Customized modules are available on request.

9.1 Packaging info

LW04-MOD comes in anti static bags in single units.

10. Revision history

V1.1.0.0 - Feature update
- Added Tunable white:
When using IEC62386 as the control interface the channels can now be run as pairs to drive cold and warm white LEDs in a tunable white mode.
- Removed LED status register:
The method for checking the LED status has been found to be ineffective and the function has been removed.
- Channel number variable for IEC62386 and DMX:
The number of channels active on IEC62386 and DMX are now configurable. In applications that do not use all four channels the inactive channels don't block addresses any more.

V1.0.0.4 - Bug fix
- Fixed IEC62386 problems:
Writing to persistent memory was delayed indefinitely if the bus power failed.
Actual Power was not reset to 254 by Reset command.

V1.0.0.3 - Bug fix
- Further optimization of output behaviour to reduce RF emissions

V1.0.0.2 - Bug fix
- Optimized output driver behaviour to increase efficiency

V1.0.0.1 - Bug fix
- Fixed maximum current to 1 A, was formerly clipped at 875 mA

V1.0.0.0
- Initial shipping version

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