HeliSource SC1 Evaluation of the TI LM3409

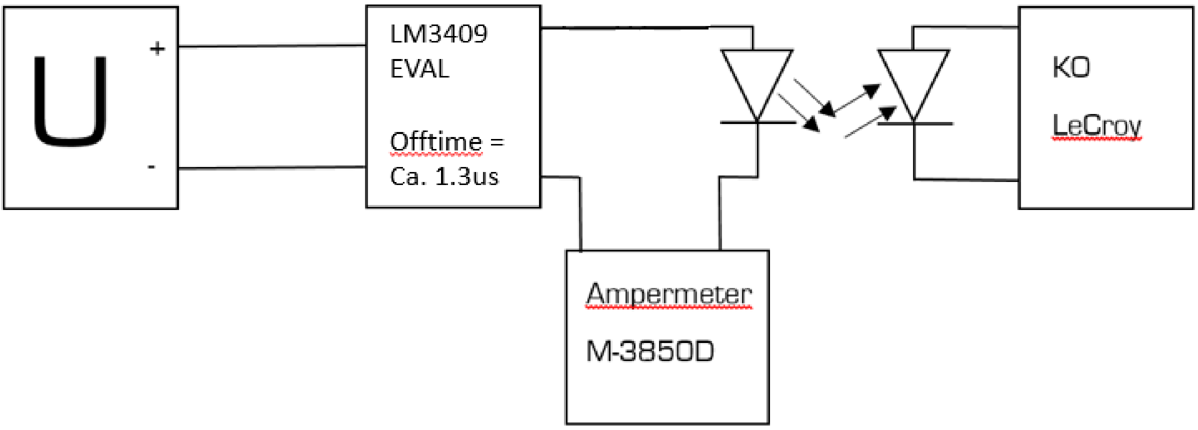
Inhalt

1. Measurements

1.1. Ripple Measuremnts

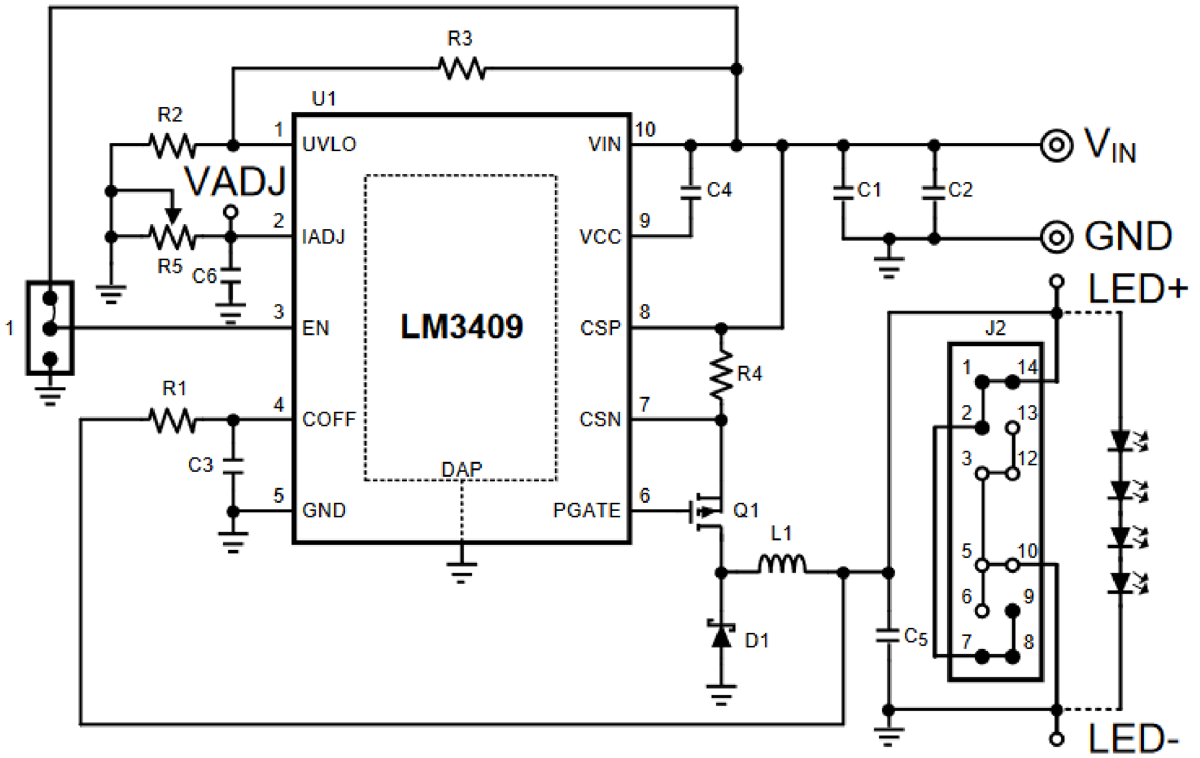
In this chapter are the test setup and the test result documented. The purpose of this chapter is to show which noises are produced by the led driver and how can we see that on the FFT. At the end of this chapter is a summary, which shows exactly the frequency and the amplitude of every noise.

1.1.1. Test setup



Power supply	Heliotis power supply 24V/12V
Evaluation Board	LM3409EVAL/NOPB-ND
LED	Luminus PT39 blue
Amperemeter	Voltcraft M-3850D
Photodiode	Thorlabs PDA36A, 0dB
KO	LeCroy waveRunner 104MXi

1.1.2. Schematic LM3409 Eva kit

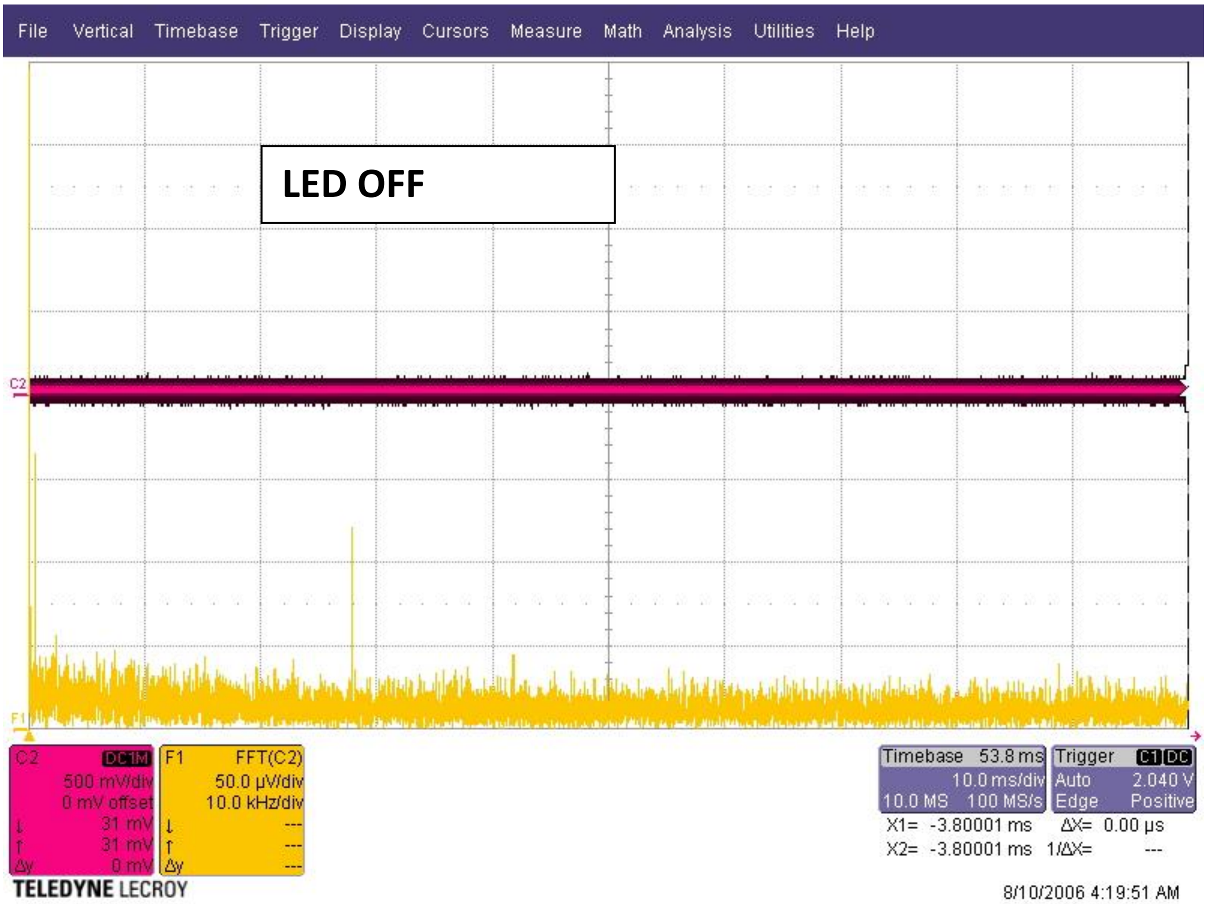


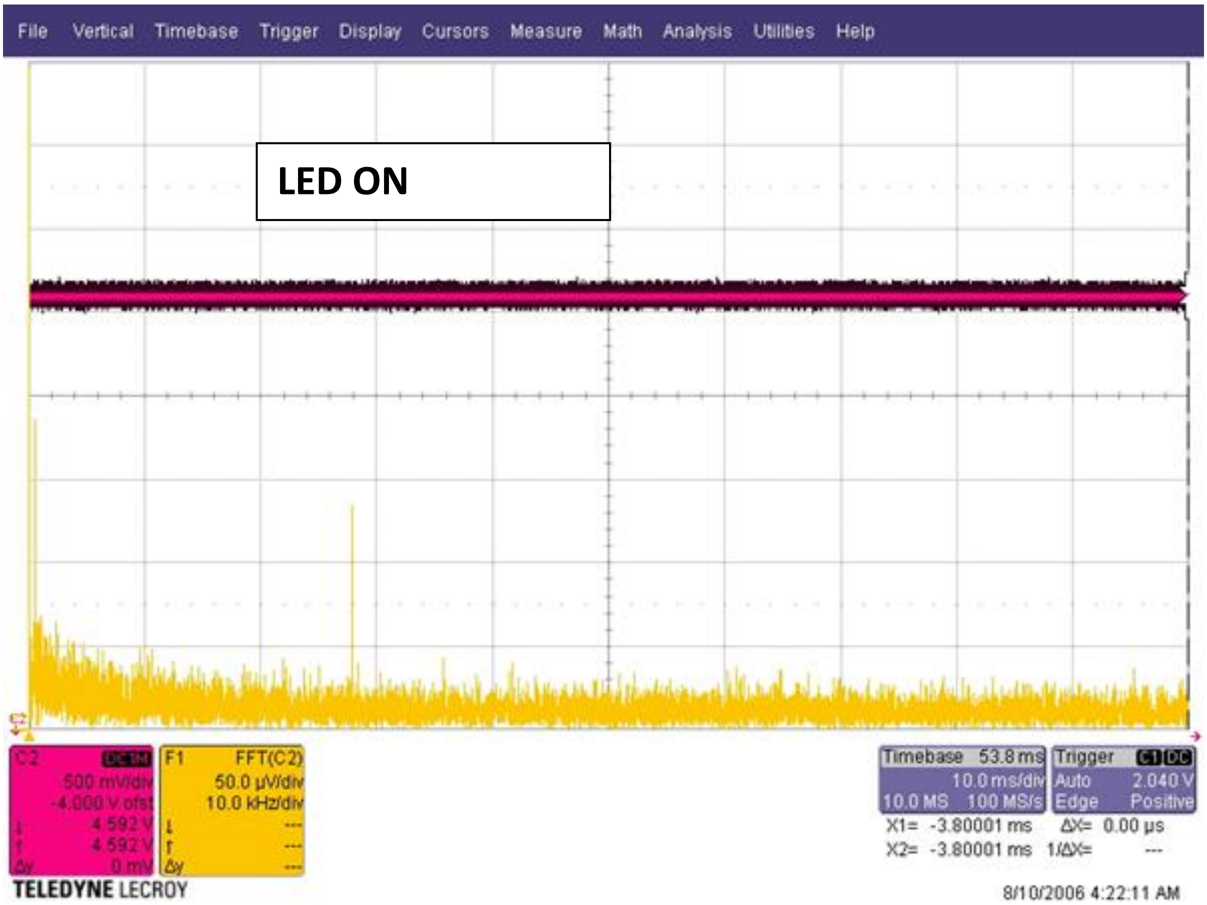
Modifications:

R1	6.2k	L1	33uH, 12A
R2	6.9k	C2	2.2mF, 35V
R3	22k	C5	400uF
R4	0.05, 0.1 or 0.2Ω		

To optimize the ripple on LED current, there is a 100uF capacitor mounted on de LED board between anode and cathode.

1.1.3. Imax = 4.9A, ILED = 4A 0-100kHz





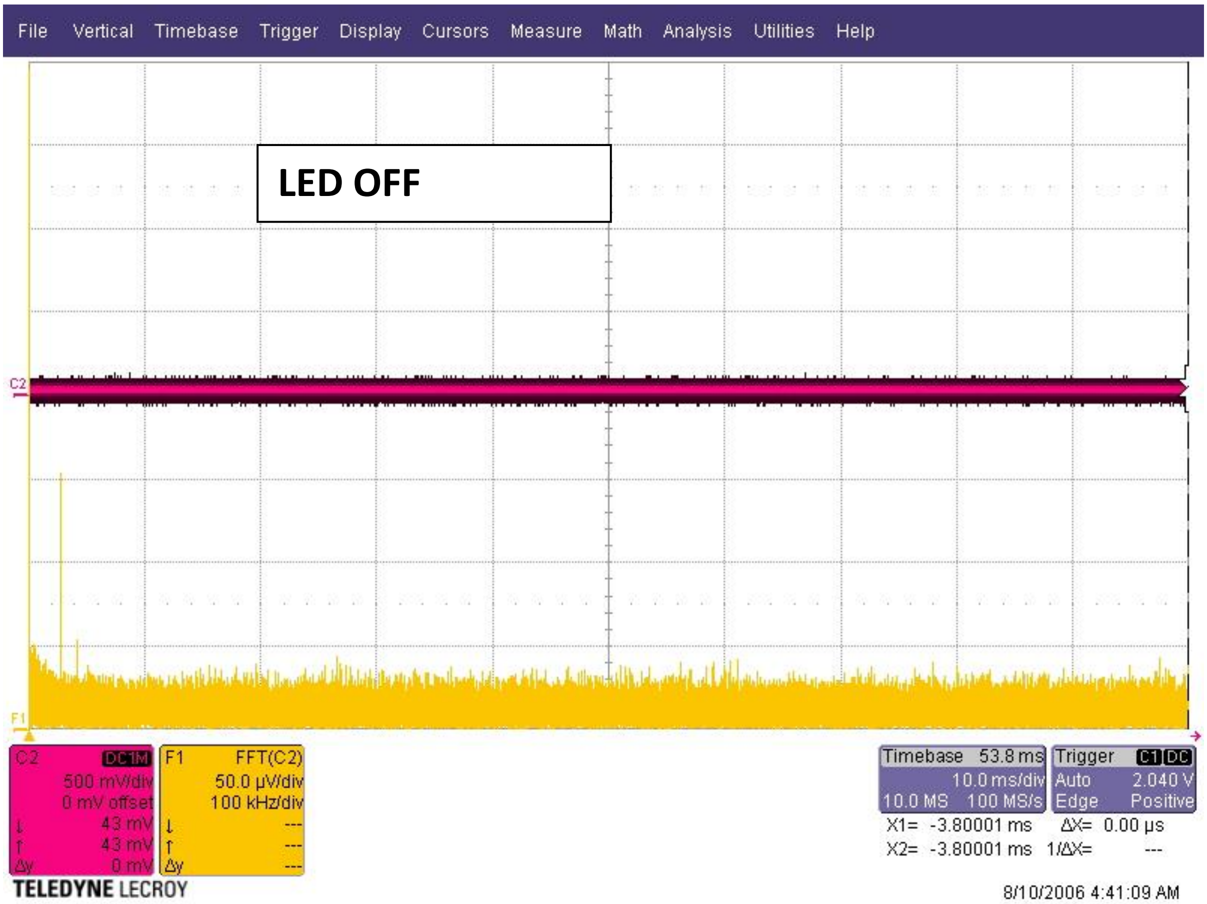
The first picture shows the base noise, which is measured even when the LED is turned off. This picture is important to understand, which noise is generated by the LED.

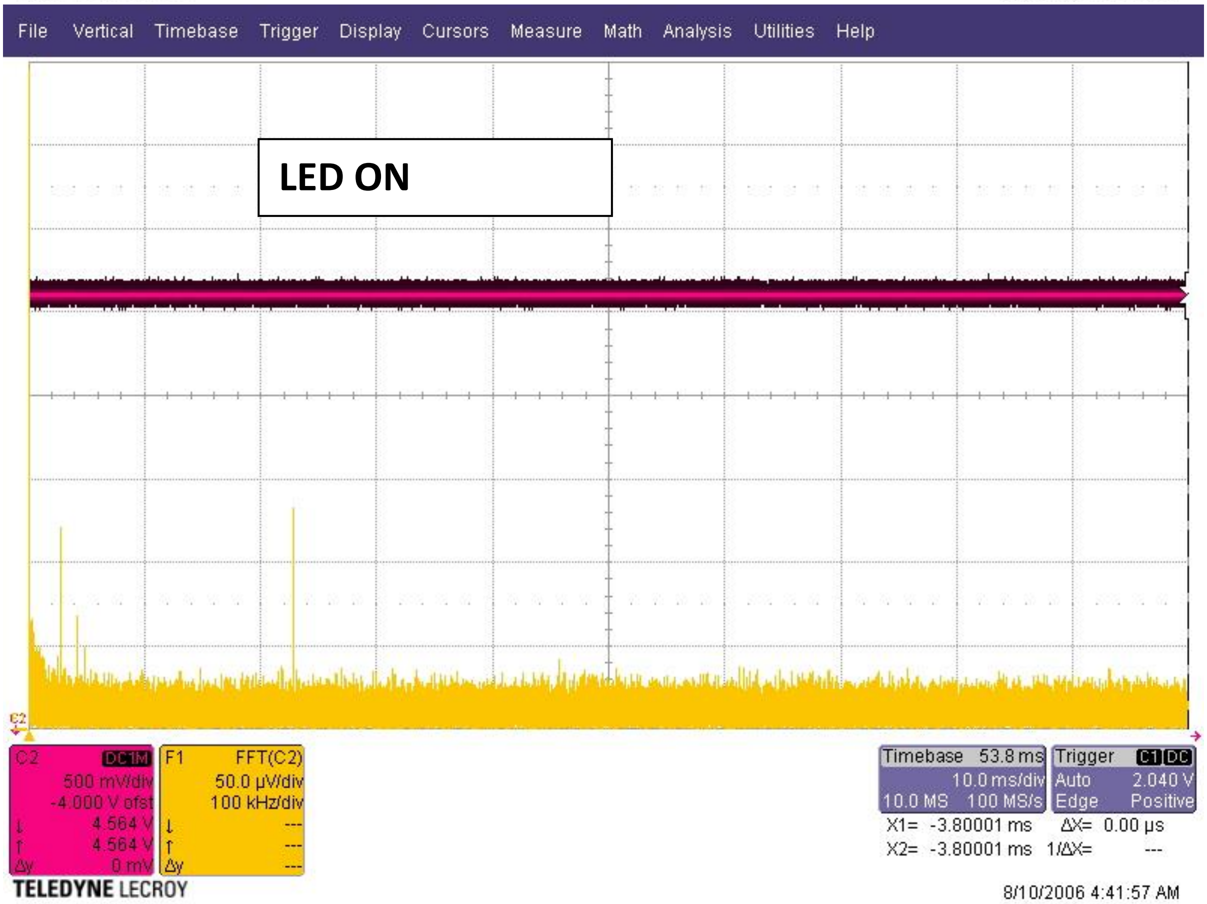
The second picture shows the noise, which is measured when the LED is turned on. Comparing the first and the second picture allows to see the noise generated by the LED. In this case, there is just a small influence between 0Hz and 5kHz

The maximal amplitude in this area is about 1.5 division (means 75uV). Theoretically the noise generated by the LED is just about 30uV (amplitude on second picture - base noise amplitude). To make a worst-case forecast it’s better to calculate with 75uV.

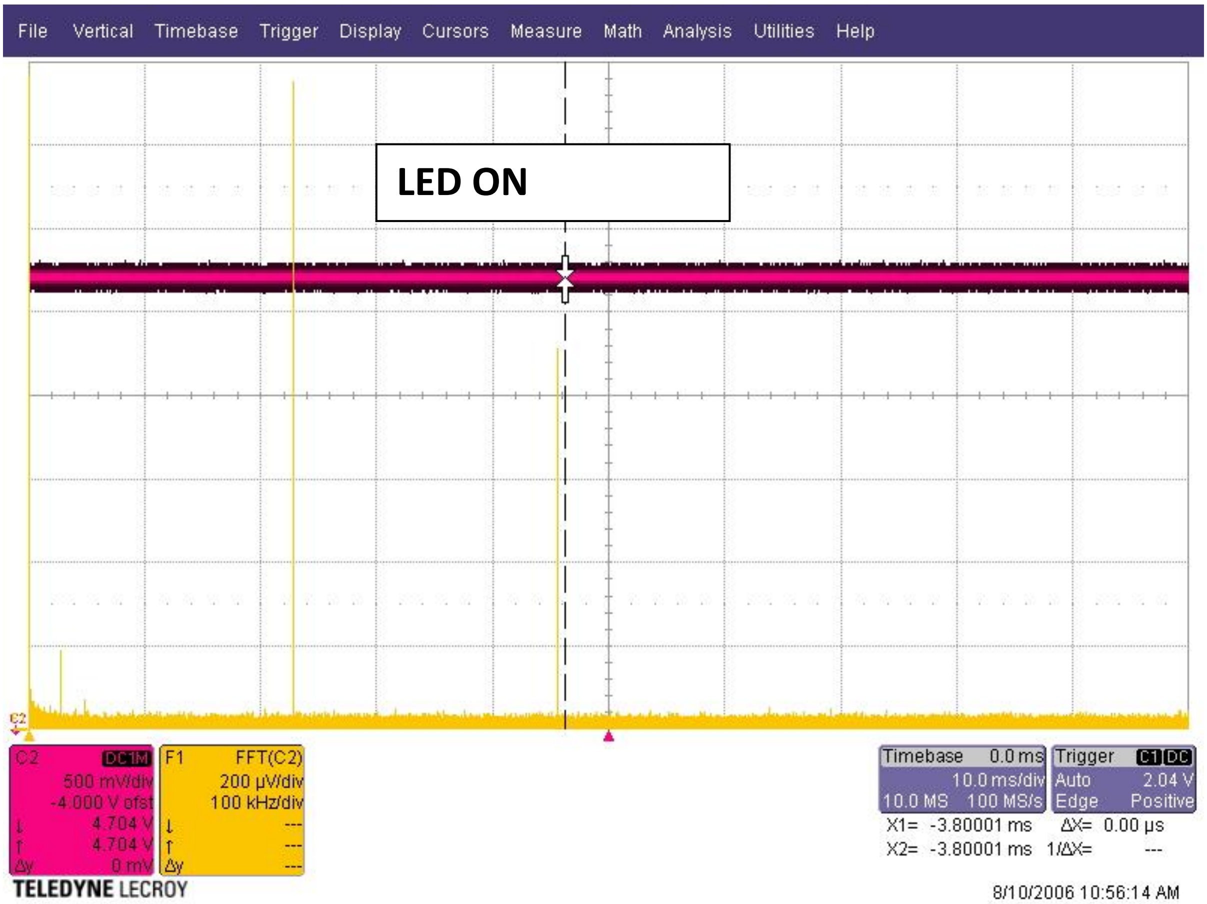
The following pictures are compared the same way. There are only additional notes, if there is something that must be explained specially.

1.1.4. Imax = 4.9A, ILED = 4.0A, 0-1MHz



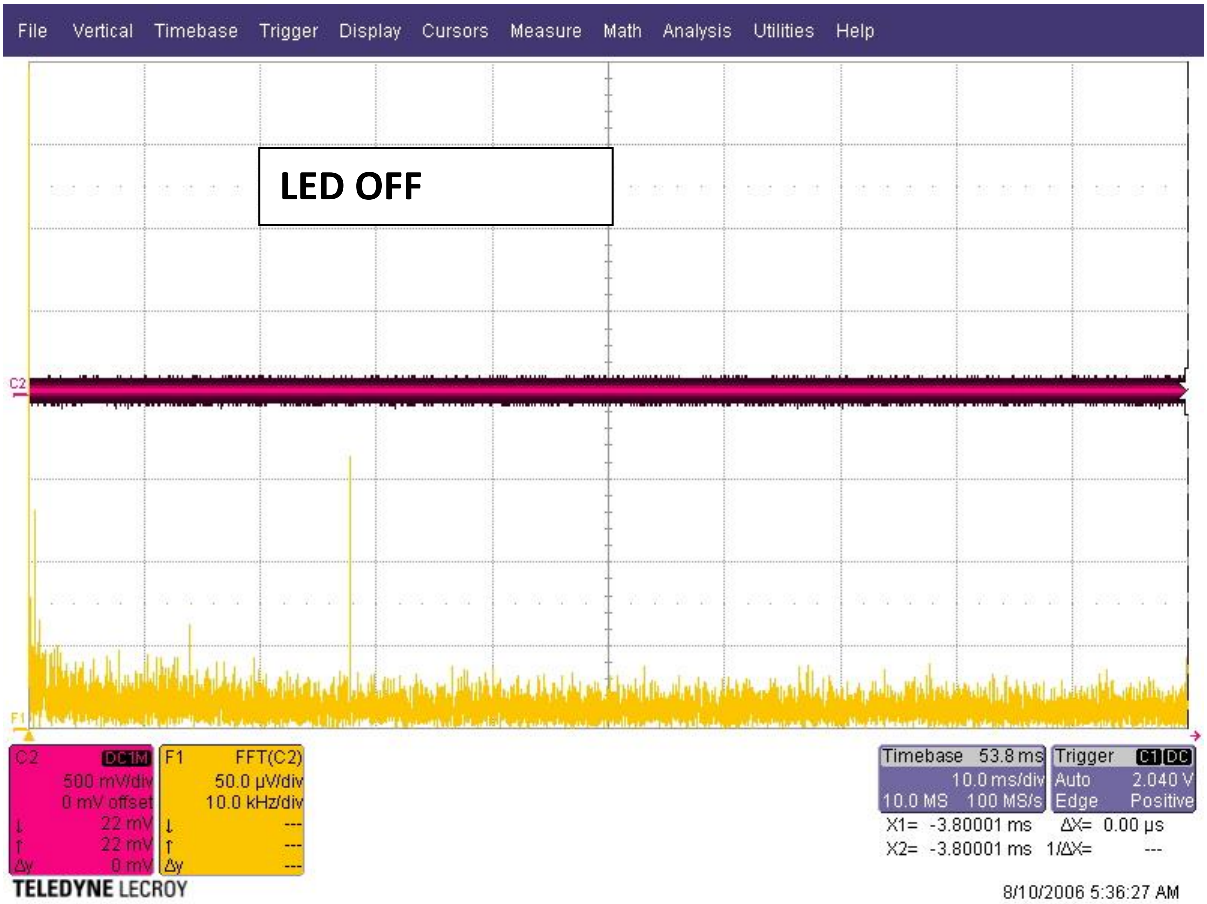


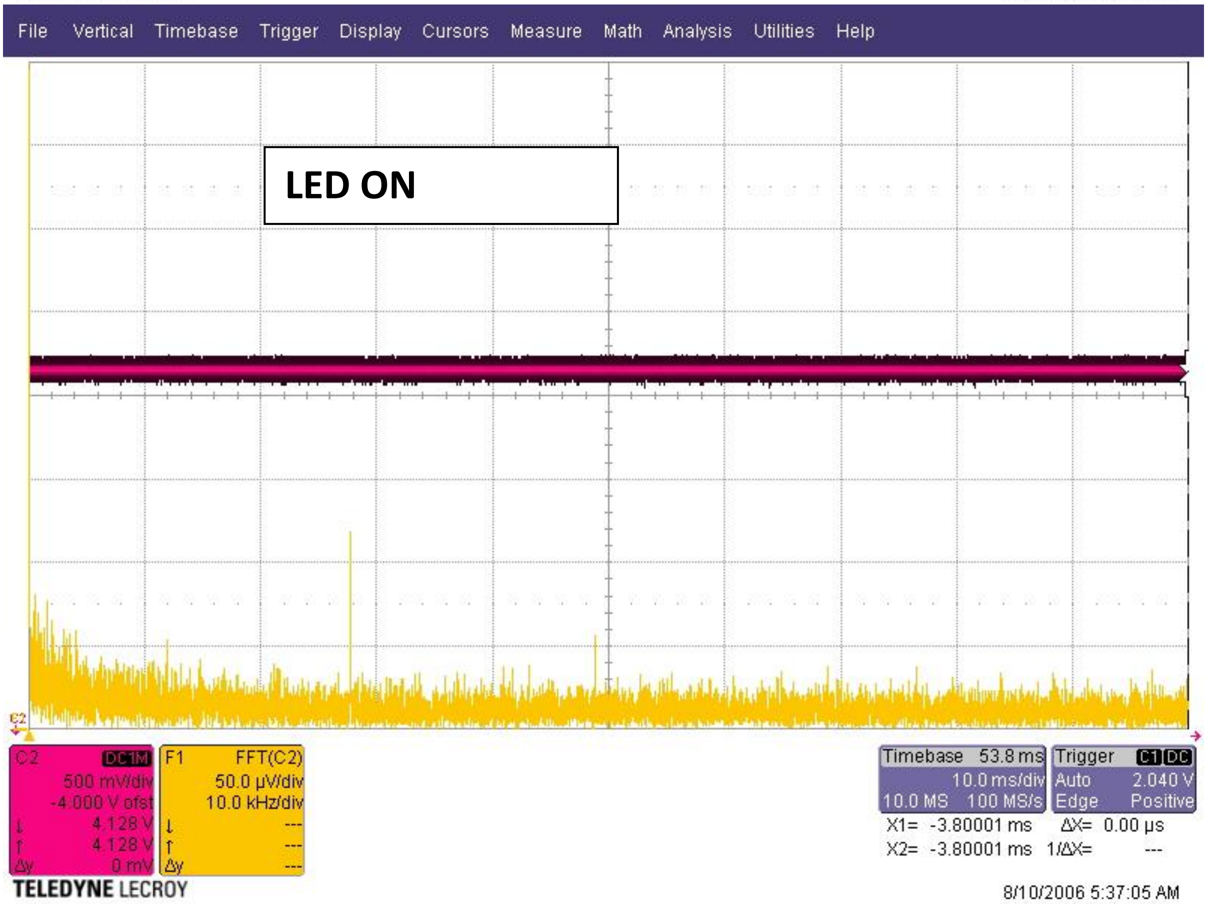
1.1.4.1. Without C_{LED}



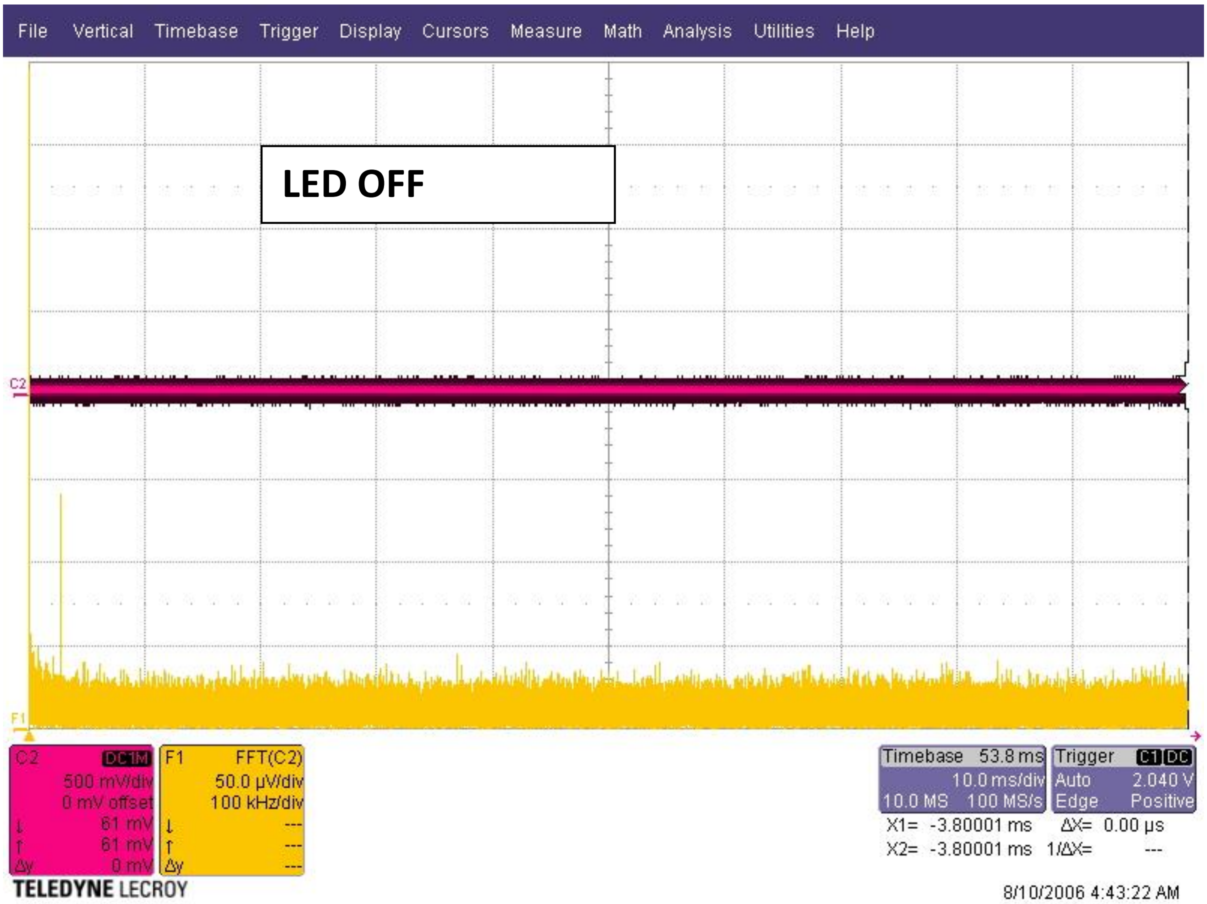
If the capacitor between anode and cathode of the LED is removed, the amplitude noise on 220khz is about 1.6mV instead of 150uV. This means the noise/signal ratio is about factor 10 bigger. In addition to, a new noise at 460kHz is measured. The amplitude of this noise is about 900uV.

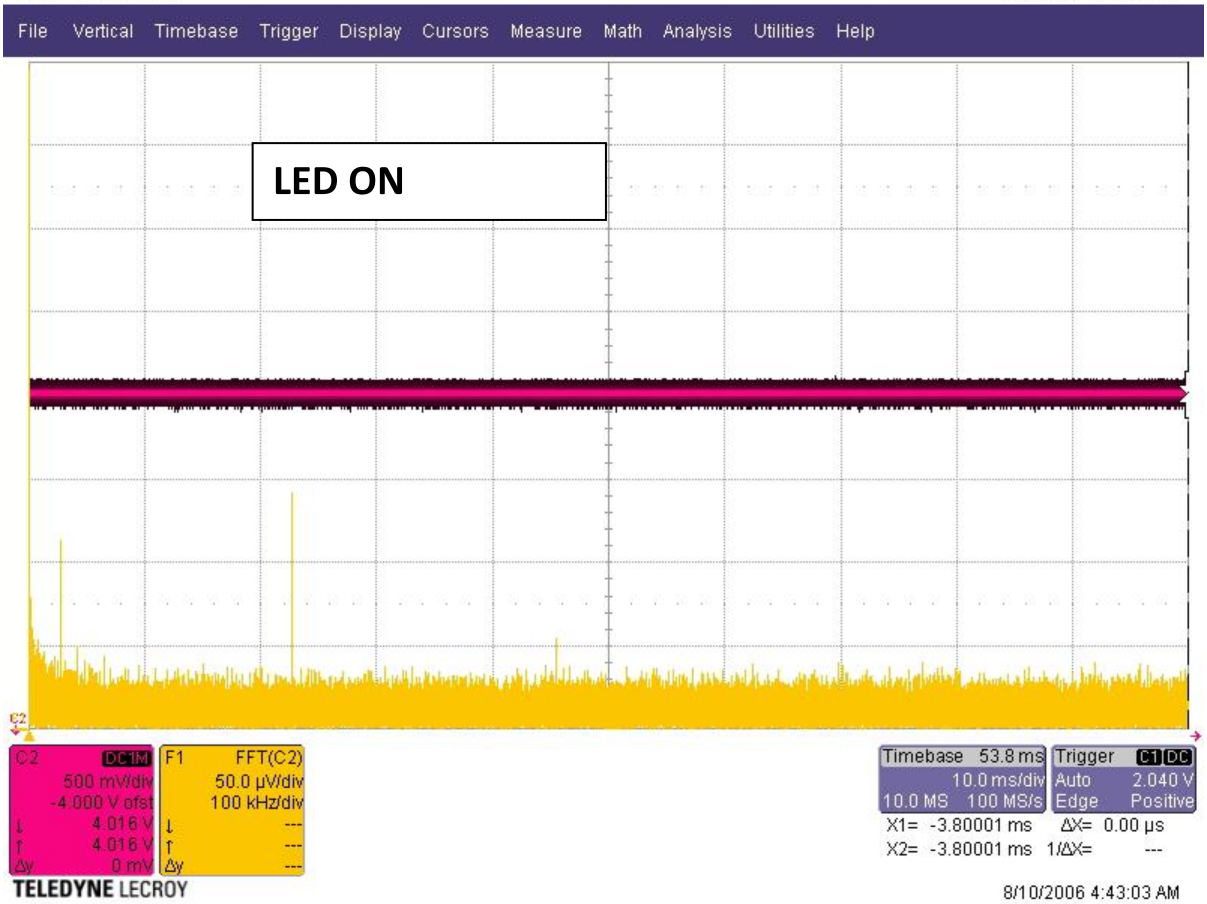
1.1.5. Imax = 4.9A, ILED = 3.5A, 0-100kHz



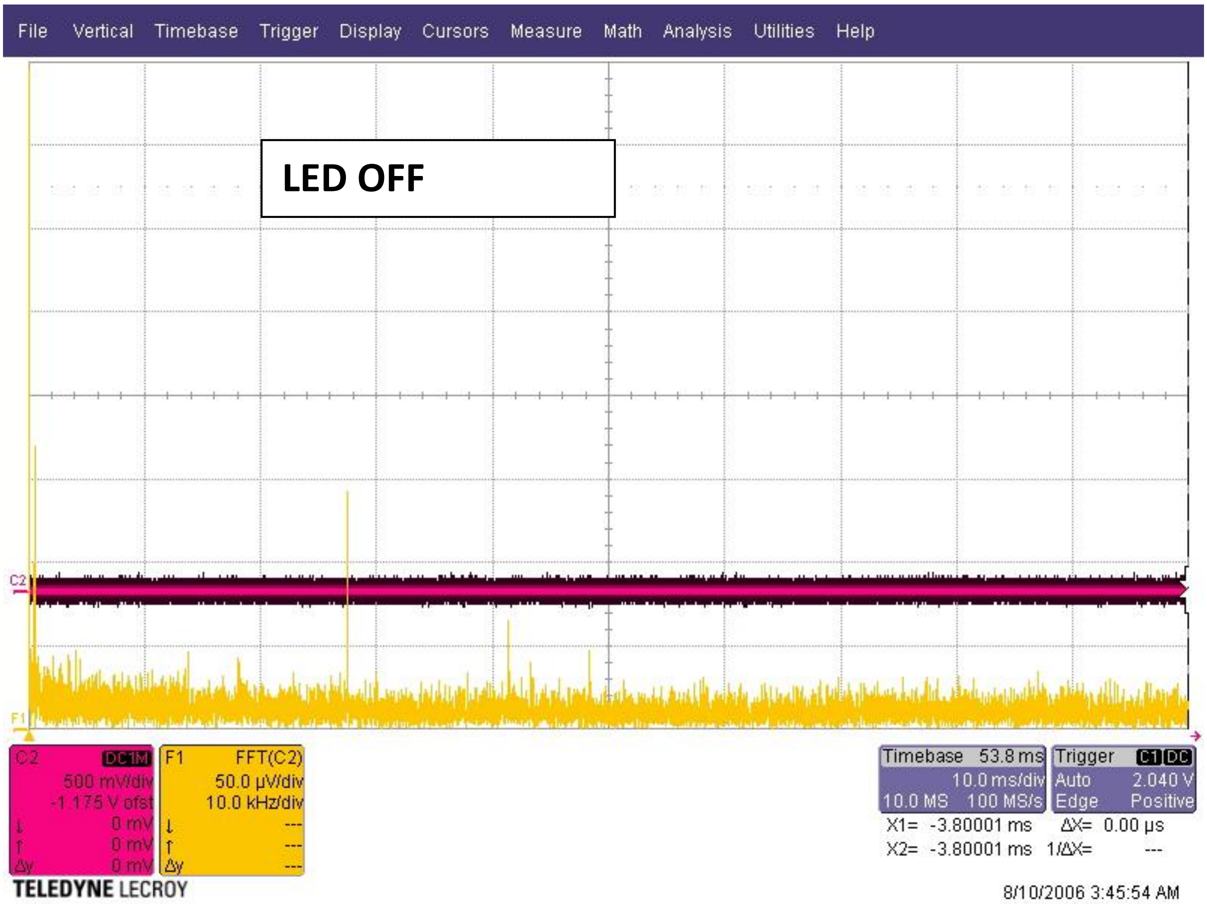


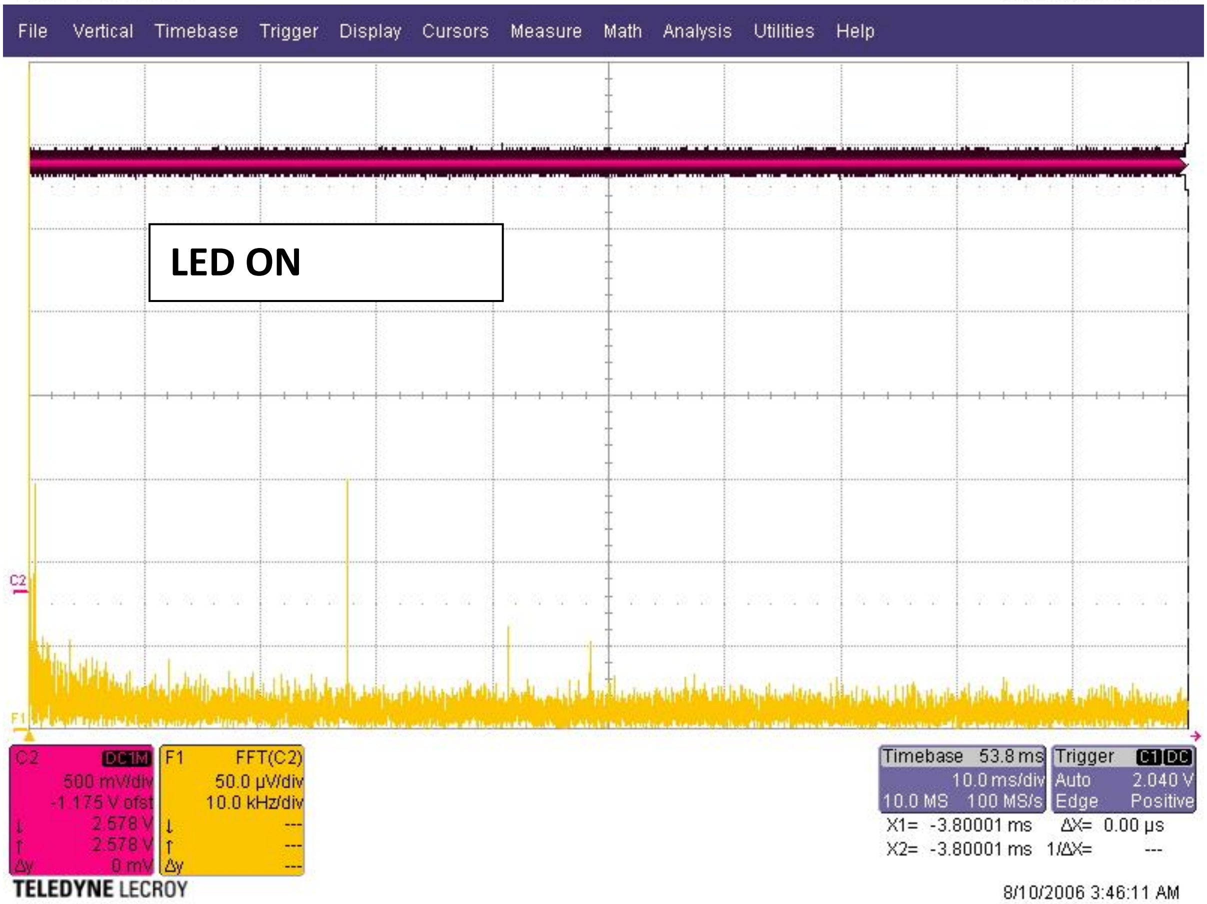
1.1.6. Imax = 4.9A, ILED = 3.5A, 0-1MHz



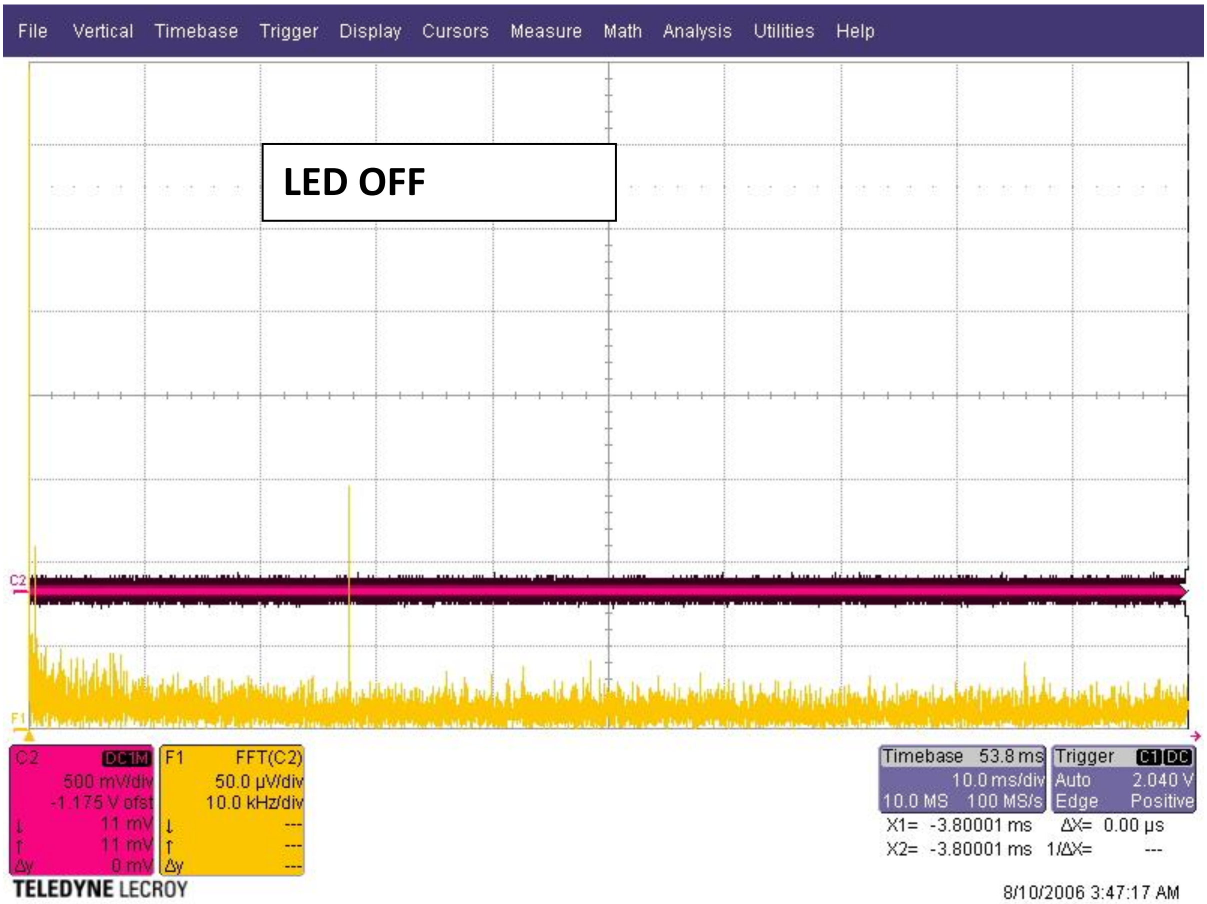


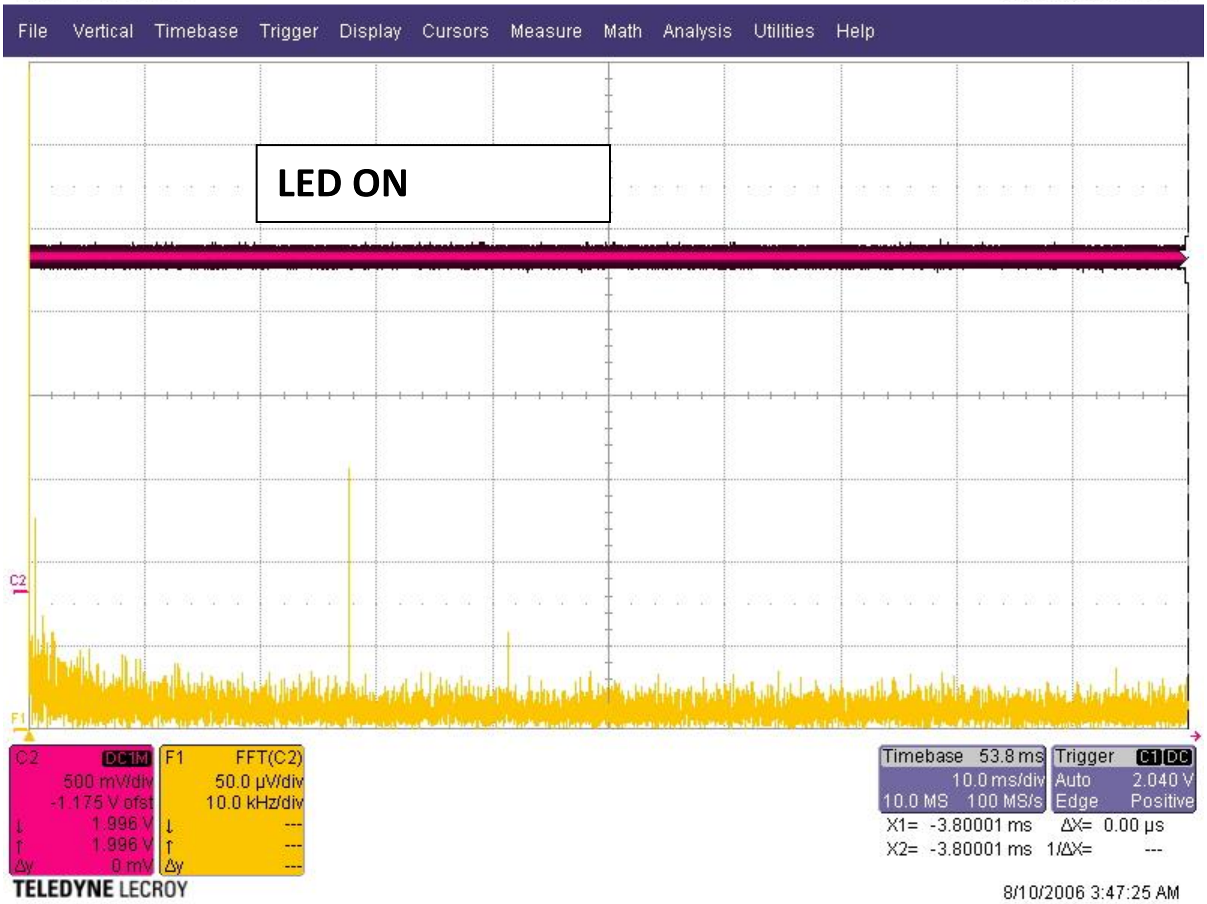
1.1.7. Imax = 2.4A, ILED = 2.0A, 0-100kHz



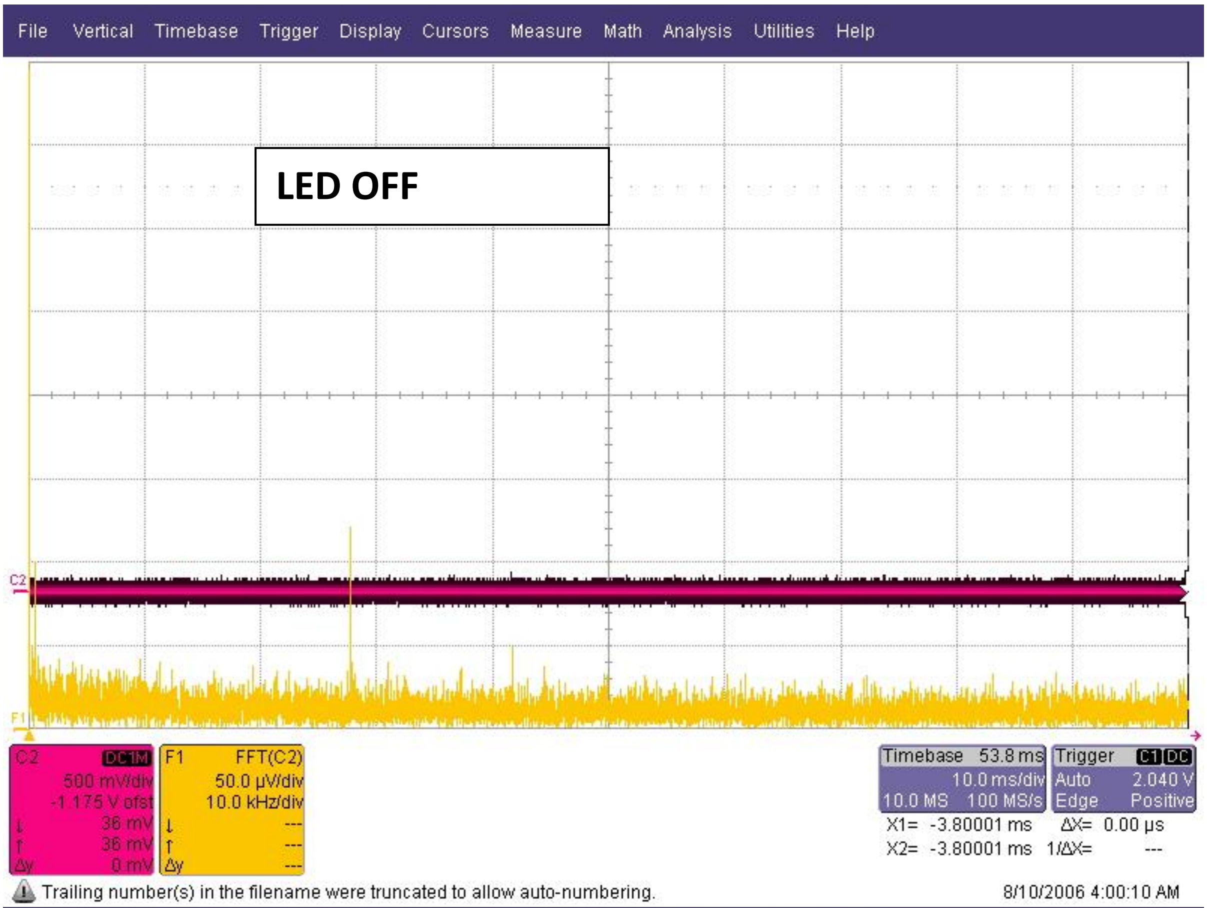


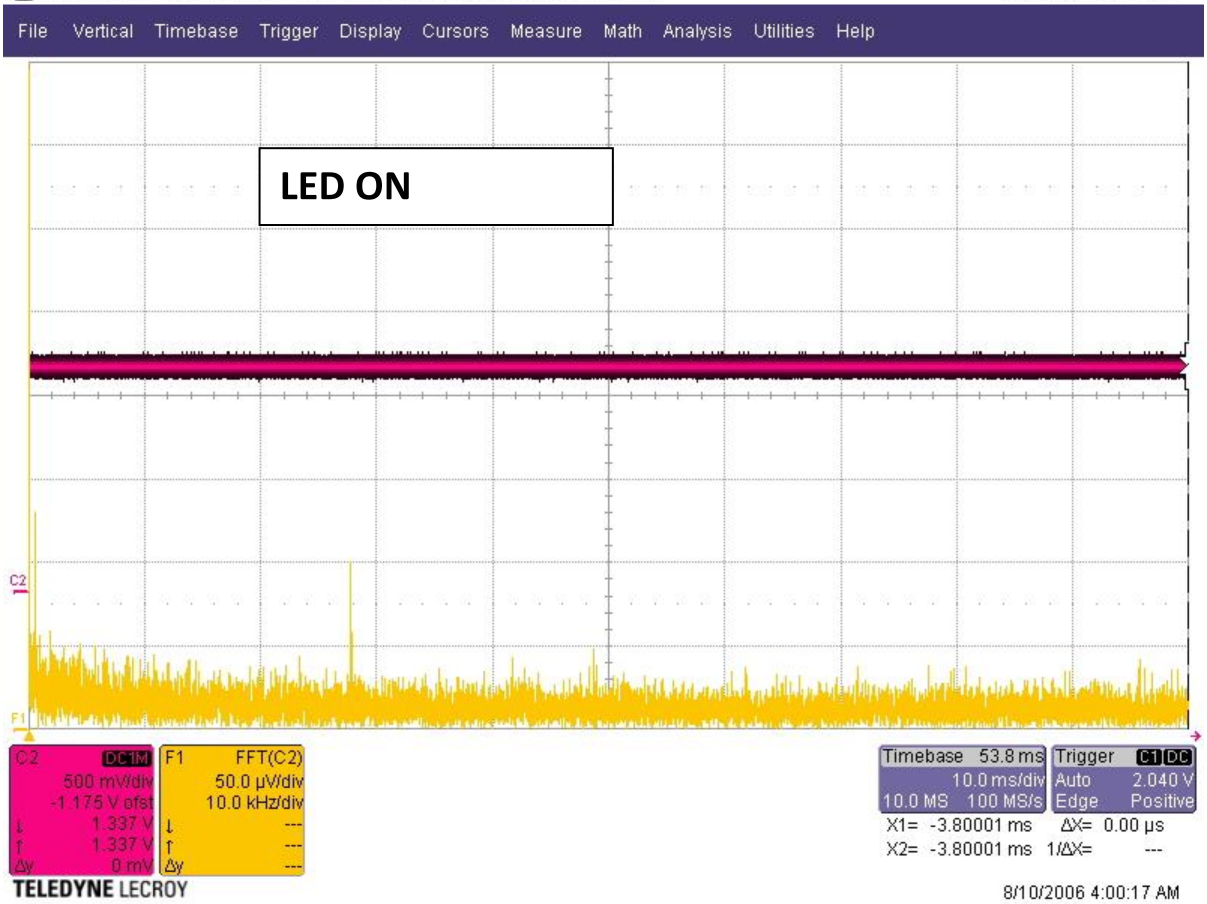
1.1.8. Imax = 2.4A, ILED = 1.5A, 0-100kHz



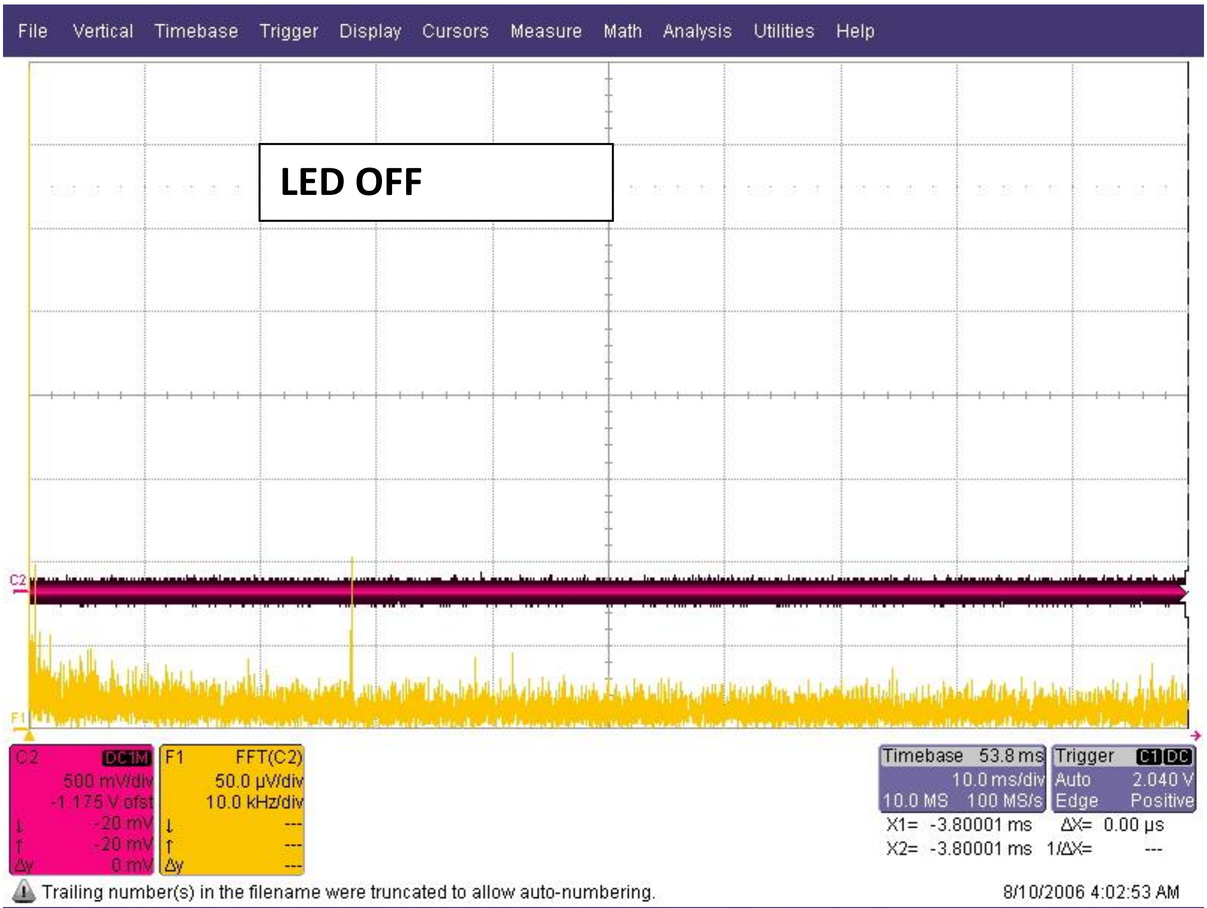


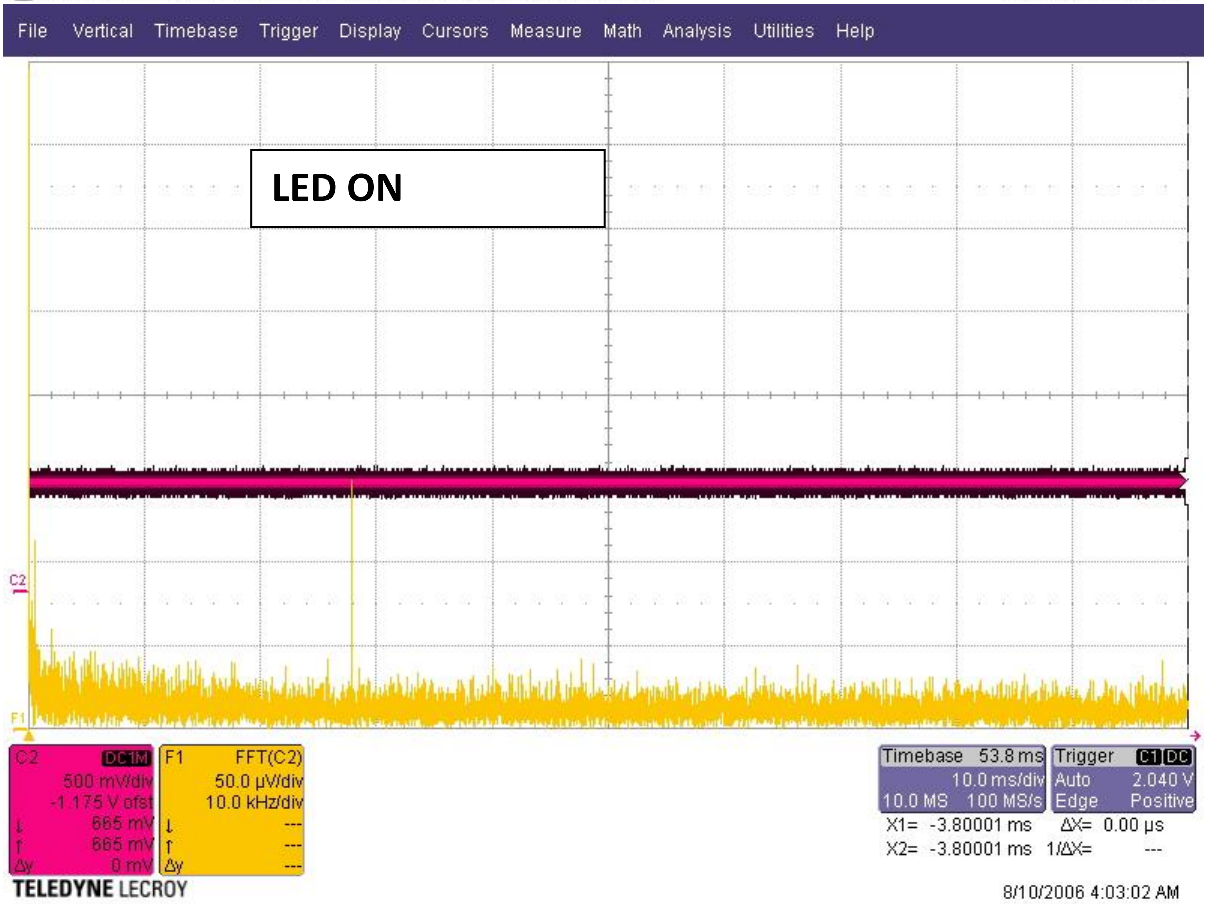
1.1.9. Imax = 1.2A, ILED = 1.0A, 0-100kHz





1.1.10. Imax = 1.2A, ILED = 0.5A, 0-100kHz

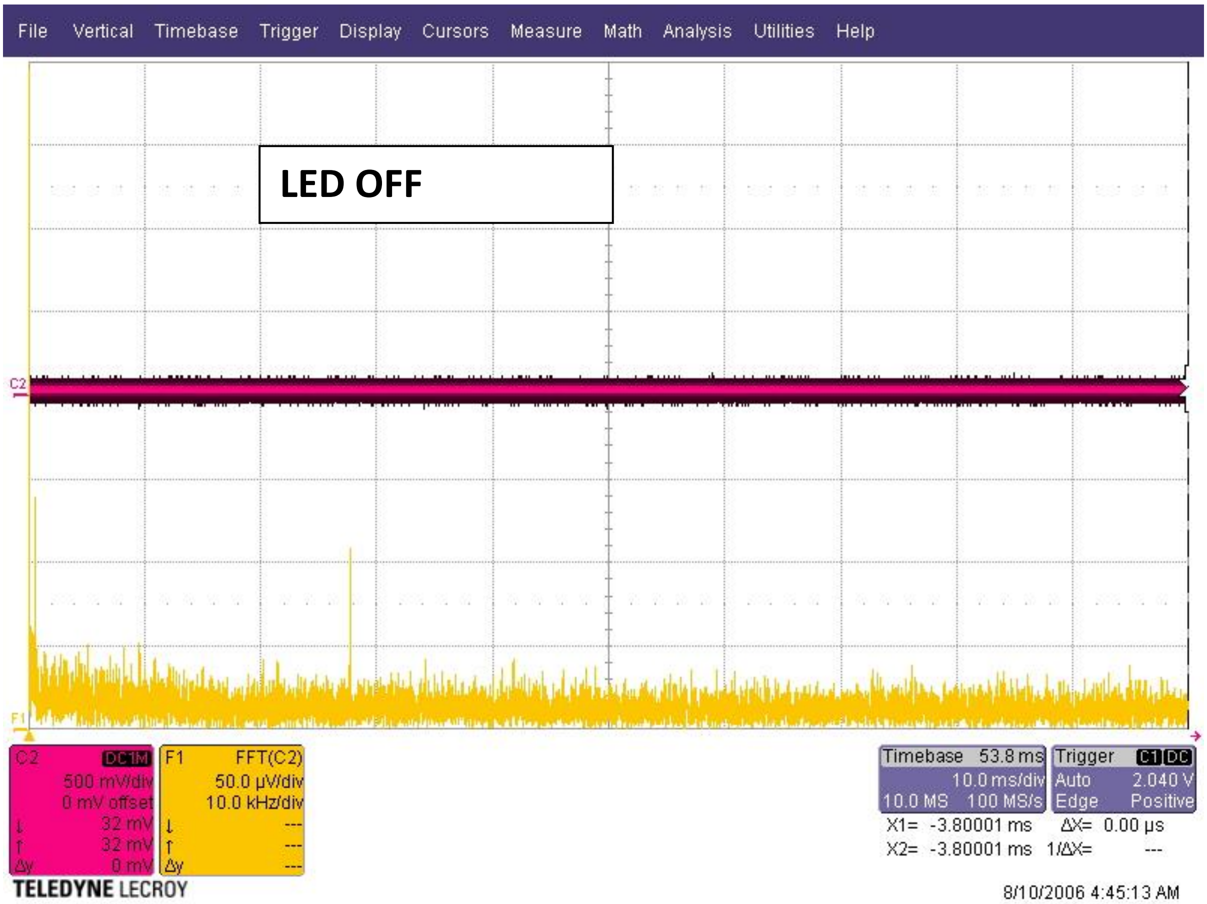


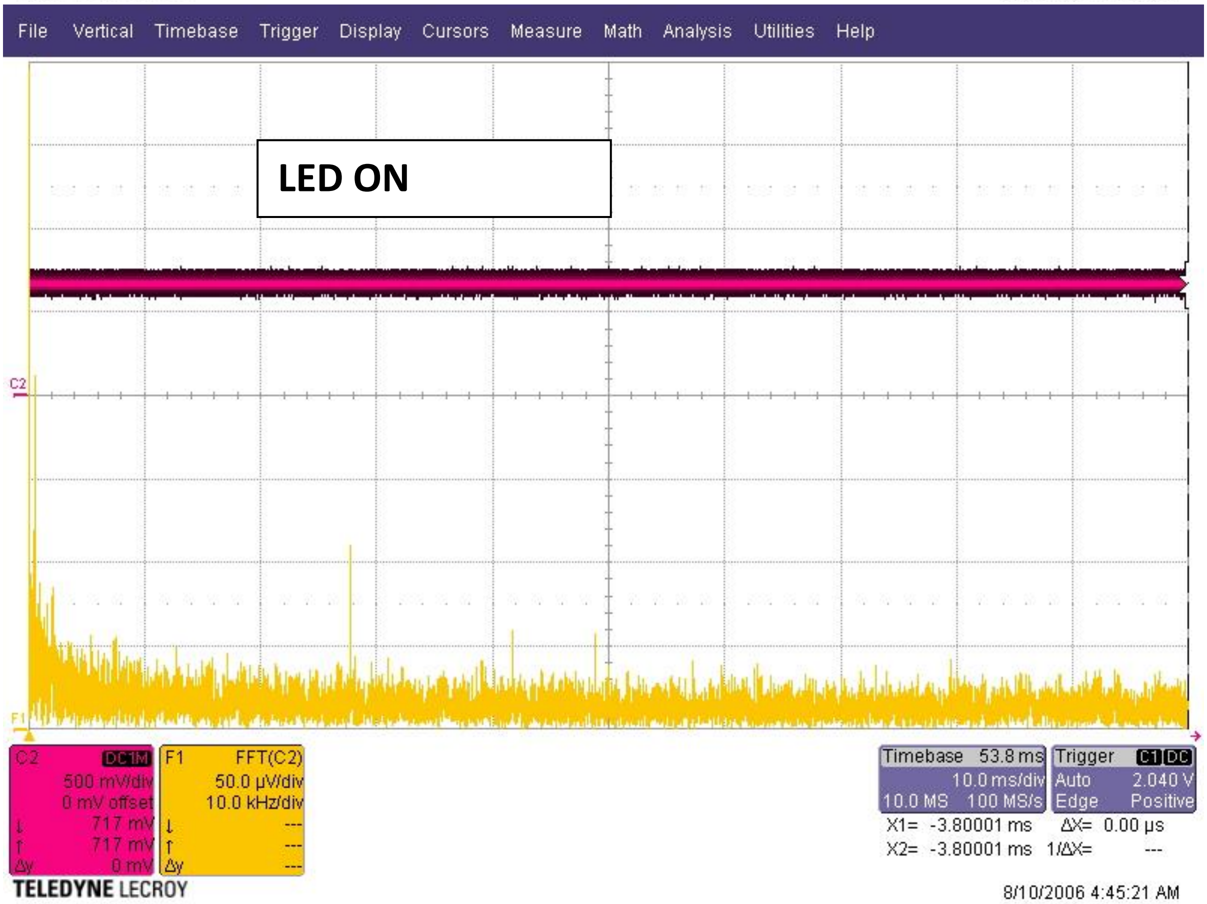


In this case the noise level on the first and on the second picture are almost identical. So, it is not possible to say if there is a noise generated by the LED or if it is just the base noise.

To make a worst-case forecast, a noise amplitude of 75uV was chosen.

1.1.11. Imax = 4.9A, ILED = 0.5A, 0-100kHz





1.1.12. Summary ripple measurement

Imax	ILED	DC	Ripple	Frequency	Ratio [‰]
4.9A	0.5A	717mV	100uV	0-5kHz	0.139
1.2A	0.5A	665mV	75uV	0-5kHz	0.113
1.2A	1.0a	1.337V	50uV	0-5kHz	0.037
2.4A	1.5A	1.996	75uV	0-5kHz	0.038
2.4A	2.0A	2.578	75uV	0-5kHz	0.029
4.9A	3.5A	4.128	75uV	0-5kHz	0.018
4.9A	3.5A	4.016	140uV	220kHz	0.035
4.9A	4.0A	4.592	75uV	0-5kHz	0.016
4.9A	4.0A	4.564	150uV	220kHz	0.033

The ratio for ILED = 0.5A isn’t out of the spec. It is just a worst-case value, that shouldn’t be reached.

The capacitor between anode and cathode of the LED mustn’t be removed otherwise the SC1 will violate the specs.

1.2. LED ON/OFF measurements

In this chapter the time which is needed to turn the LED on and OFF is measured. It is important to know, how long the HeliSource SC1 needs to be ready for measurements.

CH	I	EN	f = 10Hz
CH	II	Thorlabs Photodiode	0dB

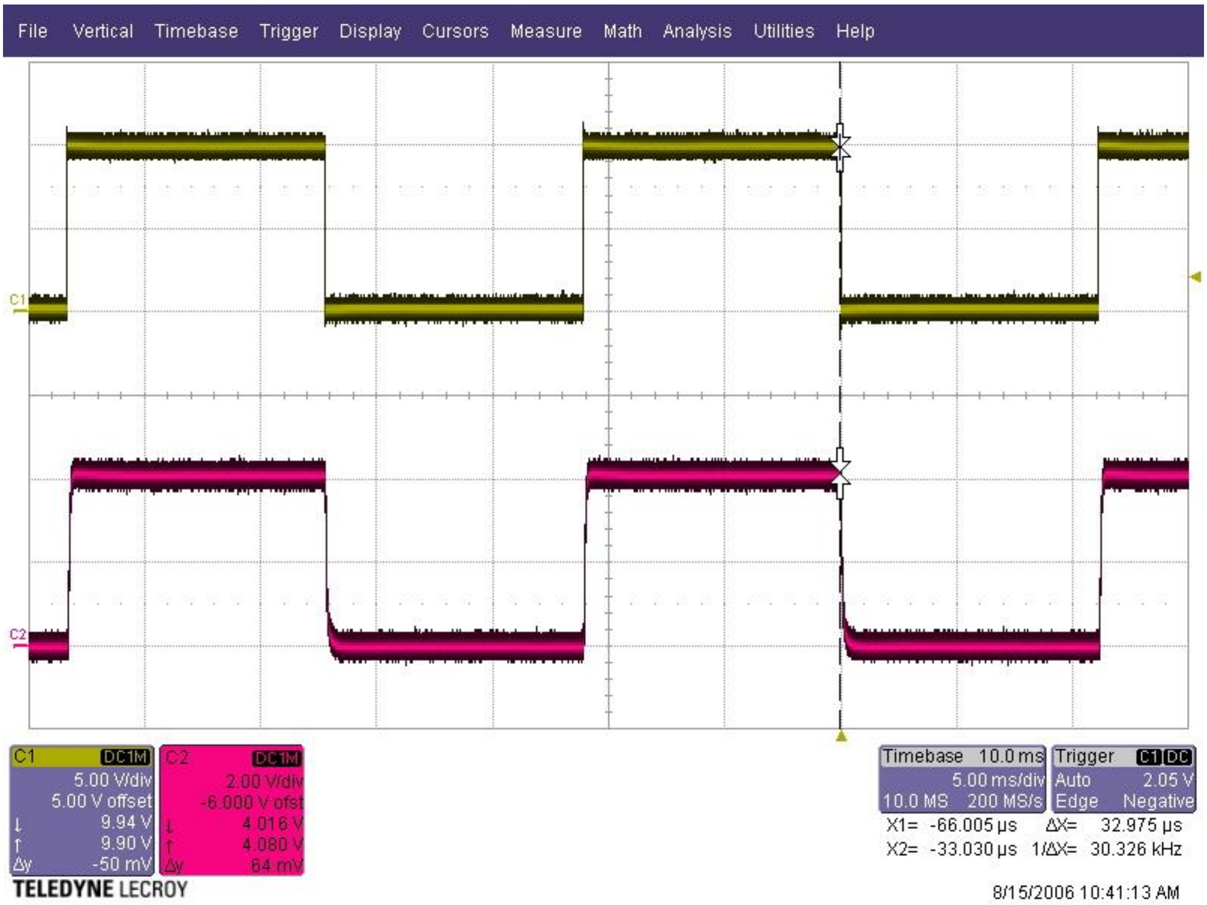
On this picture, you can see, that the voltage generated by the Photodiode, cause of the light, produced by the LED, is still rising, when the EN is set to GND, and the device is turned off. This means, that the HeliSource isn’t started up and not ready to make any measurements by constant LED current.

CH	I	EN	f = 5Hz
CH	II	Thorlabs Photodiode	0dB

On this picture, you can see, that after 80ms the voltage generated by the Photodiode, cause of the light, produced by the LED, is constant. This means, that the LED current is constant as well and the system is ready for measurement.

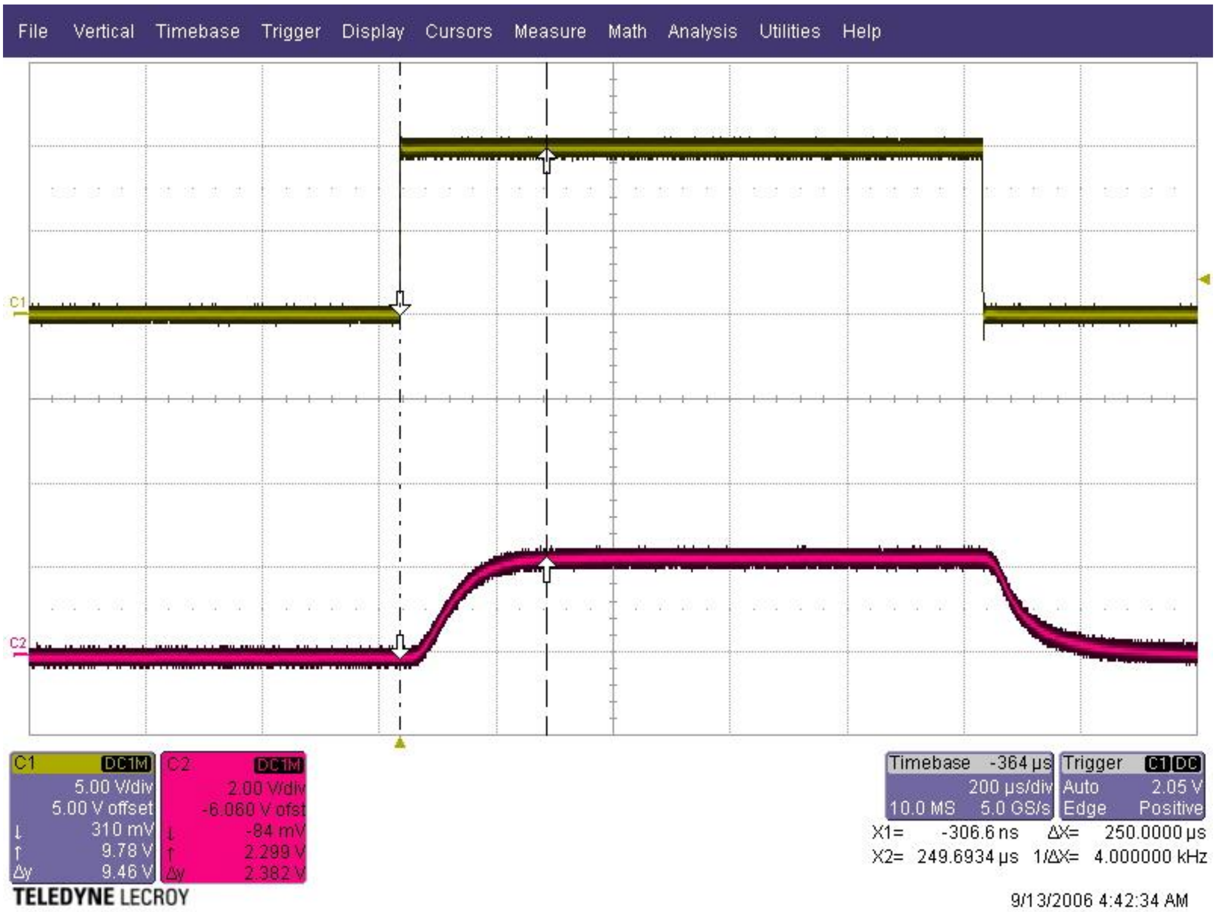
CH	I	EN	f = 5Hz
CH	II	Thorlabs Photodiode	0dB

For this measurement, the setup was modified with a 2.2kOhm resister between Vin and LED+. So a DC Offset of 2.3V was generated. Unfortunately there was no positive effect on the Current rise time.



CH	I	EN	f = 45Hz
CH	II	Thorlabs Photodiode	0dB

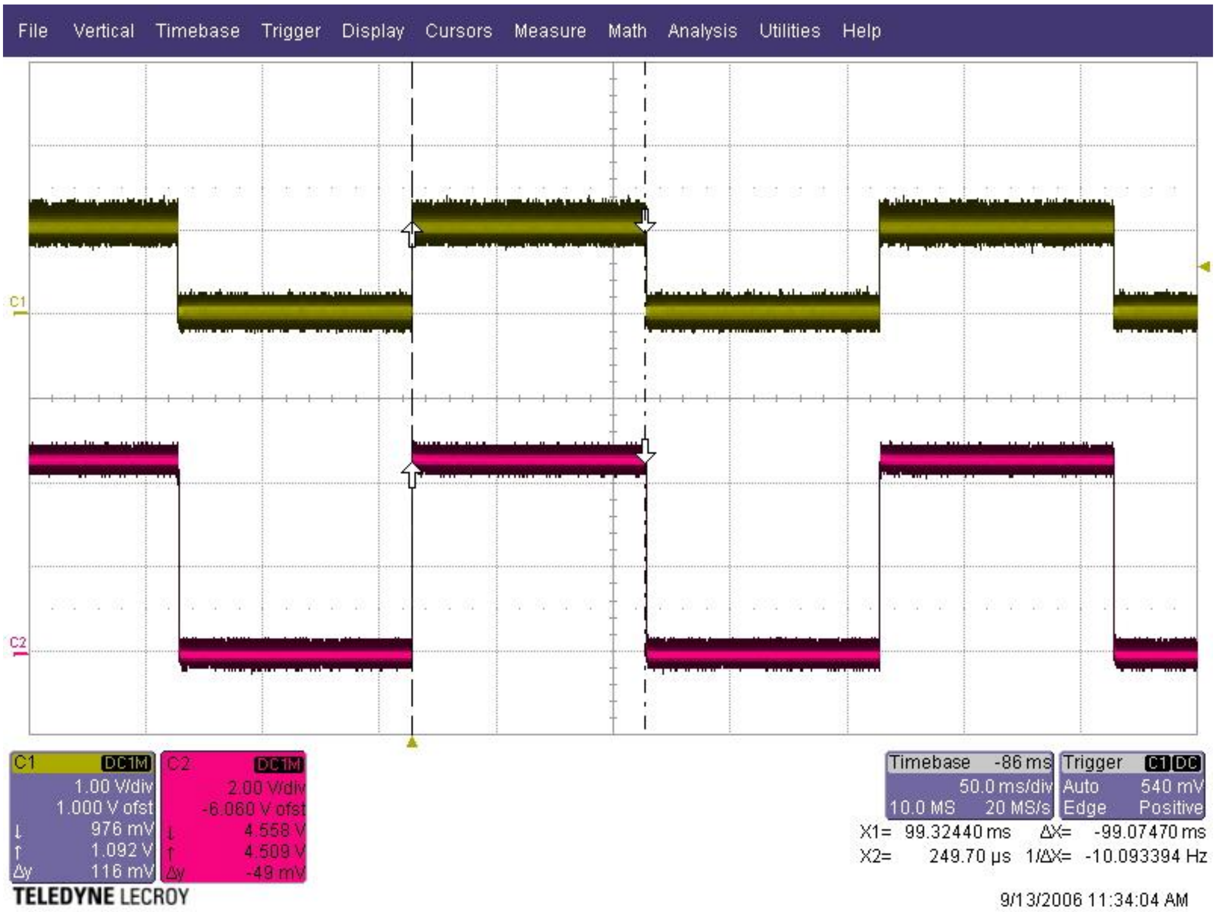
On this picture, you can see, if the frequency on EN is rising to 45Hz or higher, the rise time of the LED current (proportional to V Photodiode) is reduced. This means, that the system is faster ready for measure when the frequency at EN is 45Hz or higher.



CH	I	EN	f = 100Hz	Duty cycle = 10%
CH	II	Thorlabs Photodiode	0dB	

On this picture, you can see, if the frequency on EN is 100 Hz with a Duty cycle of 10%, the current rising delay is only 250us. This is a factor 400 faster.

Another idea was, turning off the LED using the IADJ pin.



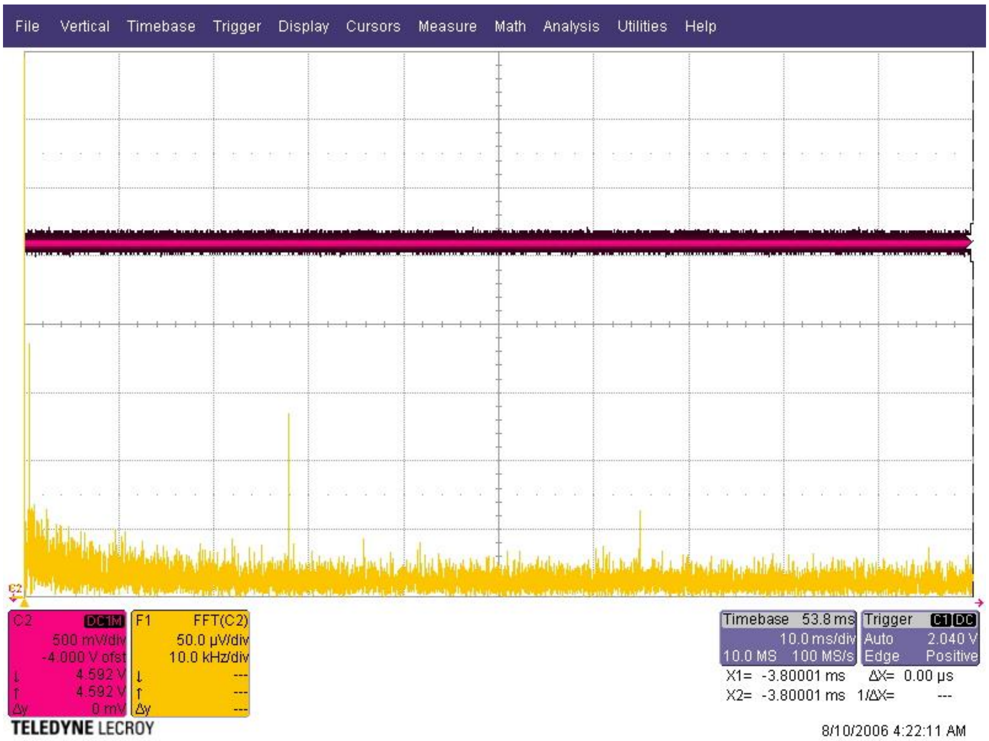
CH	I	IADJ	f = 5Hz
CH	II	Thorlabs Photodiode	0dB

On this picture, you can see, if the frequency on IADJ is 5 Hz, the LED current doesn't have a long high-rise delay. The result is as good as it was for higher frequency PWM dimming.

1.3. V_{IN} = 12V vs. V_{IN} = 24V

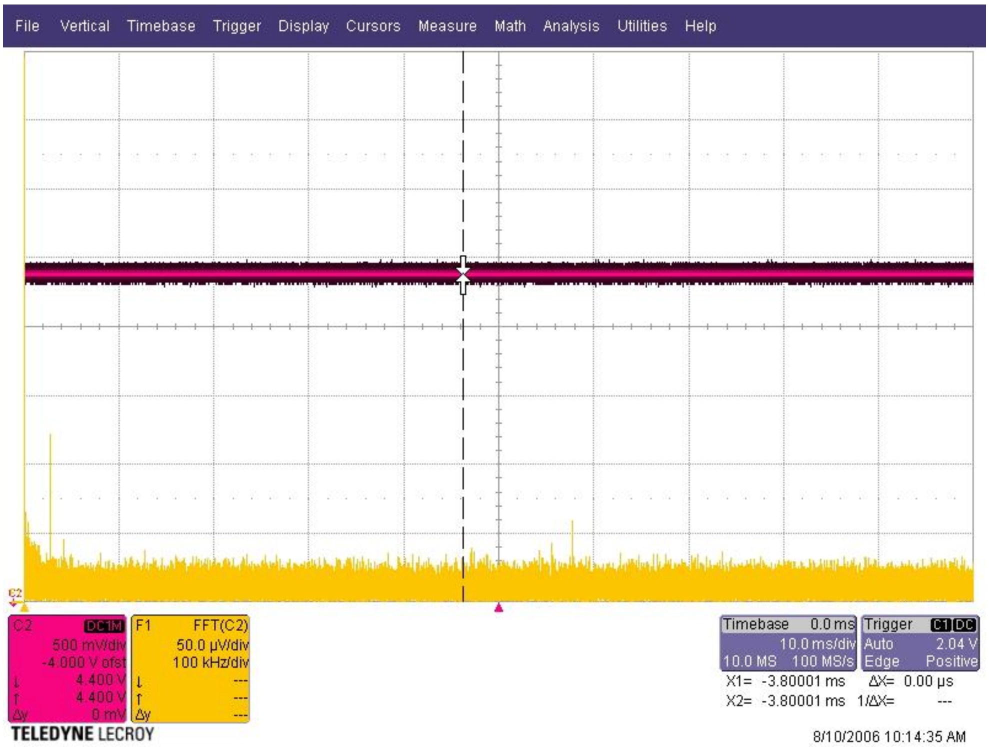
V_{IN} = 24V, ILED = 4A, 0-100kHz

V_{IN} = 12V, ILED = 4A, 0-100kHz

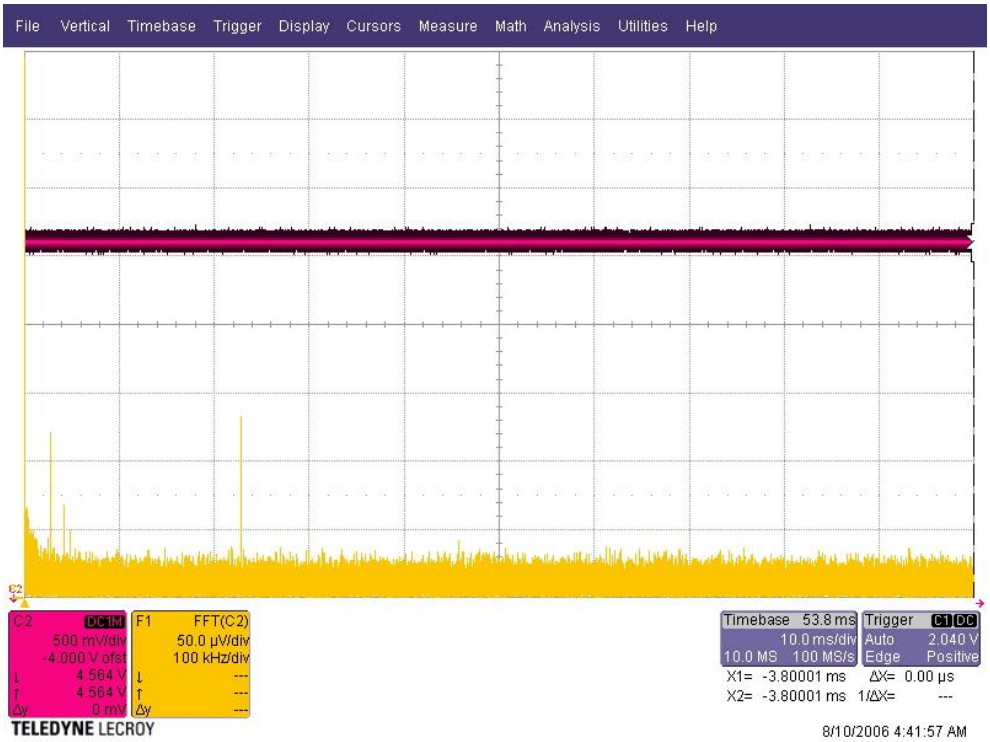


The first picture shows the noise between 0 and 100kHz, when V_{IN} is 24V. The second picture shows the noise between 0 and 100kHz, when V_{IN} is 12V. If you compare the amplitude of this noises, you will assert that there isn’t a big different between the noise level of 12V and 24V in this area of frequency.

V_{IN} = 24V, ILED 4A, 0-1MHz



V_{IN} = 12V, ILED 4A, 0-1MHz



The first picture shows the noise between 0 and 1Mhz, when V_{IN} is 24V. The second picture shows the noise between 0 and 1MHz, when V_{IN} is 12V. If you compare the amplitude of this noises, you will assert that on both pictures is a noise, but not on the same frequency. If VIN is 24V the amplitude of the noise is smaller and the frequency is higher (75uV;580kHz). For VIN is 12V the noise is about 150uV by a frequency of 220kHz.

1.4. Temperature/Efficiency measurements

In this chapter is shown how efficient the LM3409EVAL/NOPB-ND works and which component reach which temperature. So, we will know which components must be combined with a heath sink.

LM3409						
V_{IN} [V]	I_{IN} [mA]	P_{IN} [W]	V_{OUT} [V]	I_{OUT} [mA]	P_{OUT} [W]	Wirkungsgrad LM3424
12.04		0.00			0.00	#DIV/0!
12.04		0.00			0.00	#DIV/0!
12.04		0.00			0.00	#DIV/0!
12.04		0.00			0.00	#DIV/0!
12.04		0.00			0.00	#DIV/0!
12.04		0.00			0.00	#DIV/0!
12.04		0.00			0.00	#DIV/0!
12.04	1120	13.48	3.10	3510	10.88	80.7%
12.04	1384	16.66	3.15	4150	13.07	78.5%
I_{OUT} [mA]	Zeit[min]	T_{U1} [°C]	T_{L1} [°C]	T_{Q1} [°C]	T_{R4} [°C]	T_{D1} [°C]
250	2					
500	2					
1000	2					
1500	2					
2000	2					
2500	2					
3000	2					
3500	2					
4000	stabil	60	52	85	75	85

2. Achieved Specifications

The current source requirements have been written down in the document heliSource SC1 Requirements that can be found on server: R:\10_Development\02_heliotis_Components\heliSourceSC1\01_Specification\01_Requirements

The following chapter summarizes how these requirements were met with the chosen LM3409 on the available dev. Board: LM3409EVAL/NOPB-ND

2.1. Max. current

According to the data sheet the LM3409 can drive a max. current of 5A. The tests were made between 0.5A and 4.0A. According to the specifications the SC1 should be able to drive a LED current of 4A. This is absolutely no problem for the HeliSource based on the LM3409.

2.2. Ripple

The maximum ripple is below 0.1‰. To get more information see chapter 1.1.12. summary ripple measurements.

2.3. Analog Dimming

With the Analog Dimming function it's possible to set every current between 0 and 4.0A. To achieve the best result, you shouldn't dim more than 1 A. for an Example look at the table below:

SET MAX CURRENT	DIM BETWEEN
4A	4.0-3.1A
3A	3.0-2.1A
2A	2.0-1.1A
1A	1.0-0.1A

For the most applications, it is no problem when the max. current is set to 4A and ILED is dimmed to 0.5A. But the noise/signal ratio is at the worst-case about 20% higher. See chapter 1.1.12 summary ripple measurements.

2.4. ON/OFF current rise time

If the frequency at the EN pin is below 45Hz the rise time of the LED current is 80ms. Is the frequency at the EN pin higher than 45Hz the rise time of the LED current is extremely reduced. For more information see chapter 1.2. LED ON/OFF measurements.

2.5. Voltage supply

All the measurements were done with a 12V power supply. It is also possible to supply the LED-drive with 24V. It doesn't have any bad influence on the noise/signal ratio. If I LED is set on 4A, the noise at the switching frequency (12V: 220kHz, 24V: 580kHz) is reduced. This is shown in the measurements in chapter 1.3. V_{IN} = 12V vs V_{IN} = 24V.

3. Conclusion for concept

3.1. Electrical recommendations

- Increasing the output capacitors over 400uF doesn't have a positive effect on the output ripple.
- Adding a capacitor of 100uF directly on the pins of the LED, reduces the ripple on switching frequency by factor 10.
- For high output currents (over 1A) an input capacitor of 2.2mF should be added.
- For high currents is important, that the inductor can handle the high peak currents. The inductor WE 7443633300 is recommended.
- For good analog dimming results there should be as less as possible noise on the Vadj Pin.

3.2. Temperature recommendations

- To reduce the temperature on R4, it is recommended to use for high currents some resistors in parallel circuit.
- To reduce the temperature on D1 and Q1, it is recommended to make a thermal connection between the component and the case.
- The high temperature on U1 is due to the thermal connection between D1 and U1 via the ground plate.