

## Noise measurements for LEDs and zener diodes

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### DESCRIPTION OF TEST RIG

The test rig uses three current sources of approx. 1, 5 and 20 mA built using low-noise BJTs (BC559) to feed the device under test (DUT) alternately. The noise was measured using two op amps in non-inverting configuration cascaded, both having a gain of 34, making a gain of 1156 in total. The first op amp is a very-low-noise model (LT1115) and uses a gain resistor of only 10 Ohms in the feedback network. The gain resistor is thus 330 Ohms which works since the op amp is only expected to output very low-level signals. The second op amp is a low-noise type (NE5534) with gain and feedback resistors of 100 Ohms and 3.3 kOhms. The output was measured using a PC soundcard (Creative Audigy LS in 16-bit 44.1 kHz mode). Each measurement consists of a 10 second capture of the soundcard input and the RMS value for this 10 s. signal was computed. The program was calibrated (using a sine wave and an oscilloscope) to give approximately correct voltage readings and all measurements were divided by 1156 to give the equivalent input RMS noise at the first op amp, ie. at the DUT. No extra filters except what is on the soundcard were used.

### TEST METHOD

A spectrum of LED types ranging from IR to blue and of approximately the same type were measured. All LEDs were selected to have an max If of at least 20 mA, since this current was used in the test. Further four 0.5W types of zener diodes were tested, two of them (5.6 and 6.8 V) were deliberately selected close to each other but such that the 5.6 V diode should be expected to have true zener breakdown and the 6.8 V one to have avalanche breakdown. The other two were selected to be far away from this "transition region". Two 1.3W zeners were also tested to see how the power rating affects noise figures.

For each type of DUT, two devices (denoted #1 and #2 and presumably from the same batch) were tested at the three test currents 1, 5 and 20 mA and the equivalent noise at the DUT was measured and calculated as described above. For each combination of device and current, five 10-second measurements were made.

For reference, the voltage drop at each test current was also measured for one device of each type.

### MEASUREMENTS

All values are RMS values

Idle noise:

Measured idle noise of amplifier with grounded input:

0.19 0.19 0.19 0.19 0.18 uV

(The theoretical max value was calculated to 0.16 uV for 20kHz bandwidth and 0.22 uB for 40 kHz bandwidth).

Measured idle noise of amplifier with 100 Ohm source resistor:

0.26 0.25 0.24 0.26 0.26 uV

(The theoretical max value was calculated to 0.20 uV for 20kHz bandwidth and 0.28 uB for 40 kHz bandwidth).

LEDs:

(All LEDs of brand Everlight)

IR204/P1 (IR):

#1 @ 1mA: 3.7 3.7 3.7 3.7 3.7 uV

#1 @ 5mA: 0.67 0.66 0.65 0.66 0.66 uV

#1 @ 20mA: 0.24 0.23 0.24 0.23 0.23 uV  
#2 @ 1mA: 3.8 3.8 3.7 3.7 3.7 uV (Vf = 1.05 V)  
#2 @ 5mA: 0.65 0.64 0.64 0.64 0.64 uV (Vf = 1.11 V)  
#2 @ 20mA: 0.24 0.25 0.23 0.24 0.22 uV (Vf = 1.17 V)

EL202HD (red):

#1 @ 1mA: 0.31 0.32 0.31 0.31 0.32 uV  
#1 @ 5mA: 0.26 0.26 0.27 0.27 0.27 uV  
#1 @ 20mA: 0.39 0.36 0.37 0.36 0.37 uV  
#2 @ 1mA: 0.39 0.37 0.38 0.38 0.35 uV (Vf = 1.82 V)  
#2 @ 5mA: 0.32 0.30 0.30 0.30 0.31 uV (Vf = 1.89 V)  
#2 @ 20mA: 0.41 0.40 0.41 0.41 0.46 uV (Vf = 2.09 V)

EL204ID (red-orange):

#1 @ 1mA: 0.31 0.30 0.31 0.31 0.31 uV  
#1 @ 5mA: 0.25 0.26 0.26 0.26 0.24 uV  
#1 @ 20mA: 0.41 0.41 0.48 0.40 0.41 uV  
#2 @ 1mA: 0.35 0.31 0.29 0.30 0.32 uV (Vf = 1.64 V)  
#2 @ 5mA: 0.25 0.26 0.27 0.26 0.30 uV (Vf = 1.74 V)  
#2 @ 20mA: 0.40 0.40 0.39 0.40 0.41 uV (Vf = 1.90 V)

EL204YD (yellow):

#1 @ 1mA: 0.42 0.30 0.29 0.29 0.28 uV  
#1 @ 5mA: 0.28 0.26 0.25 0.33 0.27 uV  
#1 @ 20mA: 0.42 0.39 0.39 0.40 0.40 uV  
#2 @ 1mA: 0.31 0.30 0.31 0.30 0.31 uV (Vf = 1.78 V)  
#2 @ 5mA: 0.28 0.47 0.28 0.26 0.25 uV (Vf = 1.87 V)  
#2 @ 20mA: 0.34 0.34 0.35 0.34 0.34 uV (Vf = 2.02 V)

EL204GD (green):

#1 @ 1mA: 0.68 0.50 0.50 0.47 0.46 uV  
#1 @ 5mA: 0.35 0.30 0.28 0.28 0.29 uV  
#1 @ 20mA: 0.36 0.35 0.35 0.35 0.35 uV  
#2 @ 1mA: 0.46 0.46 0.44 0.44 0.41 uV (Vf = 1.82 V)  
#2 @ 5mA: 0.36 0.33 0.32 0.33 0.32 uV (Vf = 1.92 V)  
#2 @ 20mA: 0.39 0.40 0.39 0.41 0.40 uV (Vf = 2.12 V)

EL204UBD (blue):

#1 @ 1mA: 4.6 4.5 4.6 4.5 4.6 uV  
#1 @ 5mA: 3.2 3.2 3.2 3.2 3.2 uV  
#1 @ 20mA: 2.8 2.8 2.7 2.7 2.7 uV  
#2 @ 1mA: 4.4 4.4 4.3 4.2 4.3 uV (Vf = 3.26 V)  
#2 @ 5mA: 3.1 3.2 3.2 3.1 3.2 uV (Vf = 3.44 V)  
#2 @ 20mA: 2.9 2.8 2.8 2.8 2.7 uV (Vf = 3.69 V)

Zeners:

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(All zeners of brand Temic.)

BZX55/C2V7 (0.5W 2.7V):

#1 @ 1mA: 1.1 1.1 1.1 1.1 1.1 uV  
#1 @ 5mA: 1.0 0.88 0.85 0.86 0.87 uV  
#1 @ 20mA: 1.0 0.81 0.72 0.72 1.1 uV  
#2 @ 1mA: 1.2 1.1 1.1 1.1 1.1 uV (Vr = 2.03 V)  
#2 @ 5mA: 0.91 0.88 0.87 0.86 0.85 uV (Vr = 2.50 V)  
#2 @ 20mA: 1.1 0.80 0.77 0.73 0.71 uV (Vr = 3.02 V)

BZX55/CSV6 (0.5W 5.6V):

#1 @ 1mA: 5.3 5.3 5.3 5.3 5.3 uV  
#1 @ 5mA: 2.9 2.9 2.9 2.9 2.9 uV  
#1 @ 20mA: 1.7 1.6 1.6 1.6 1.6 uV  
#2 @ 1mA: 5.3 5.3 5.3 5.3 5.3 uV (Vr = 5.68 V)  
#2 @ 5mA: 2.9 2.9 2.9 2.9 2.9 uV (Vr = 5.77 V)  
#2 @ 20mA: 1.8 1.6 1.6 1.6 1.6 uV (Vr = 5.81 V)

BZX55/C6V8 (0.5W 6.8V):

#1 @ 1mA: 16 16 16 16 16 uV  
#1 @ 5mA: 21 21 21 21 21 uV  
#1 @ 20mA: 5.8 5.5 5.5 5.5 5.6 uV  
#2 @ 1mA: 25 25 25 25 25 uV (Vr = 6.93 V)  
#2 @ 5mA: 13 13 13 13 13 uV (Vr = 6.96 V)  
#2 @ 20mA: 4.6 4.7 4.5 4.5 4.4 uV (Vr = 7.00 V)

(Rechecked both devices due to their inconsistent behaviour for 1 and 5mA).

BZX55/C12 (0.5W 12V):

#1 @ 1mA: 0.35 0.37 0.37 0.39 0.39 uV

#1 @ 5mA: 0.30 0.28 0.28 0.28 0.30 uV  
#1 @ 20mA: 0.24 0.25 0.25 0.26 0.25 uV  
#2 @ 1mA: 0.32 0.33 0.32 0.33 0.32 uV (Vr = 11.32 V)  
#2 @ 5mA: 0.26 0.26 0.27 0.32 0.26 uV (Vr = 11.37 V)  
#2 @ 20mA: 0.25 0.26 0.28 0.24 0.30 uV (Vr = 11.42 V)

BZX85/C2V7 (1.3W 2.7V):

#1 @ 1mA: 0.77 0.77 0.77 0.77 0.76 uV  
#1 @ 5mA: 0.62 0.61 0.63 0.61 0.60 uV  
#1 @ 20mA: 0.55 0.55 0.54 0.55 0.55 uV  
#2 @ 1mA: 0.78 0.78 0.78 0.78 0.78 uV (Vr = 1.30 V)  
#2 @ 5mA: 0.62 0.62 0.61 0.62 0.62 uV (Vr = 1.61 V)  
#2 @ 20mA: 0.57 0.56 0.57 0.56 0.56 uV (Vr = 1.92 V)

BZX85/C12 (1.3W 12V):

#1 @ 1mA: 0.49 0.53 0.48 0.50 0.52 uV  
#1 @ 5mA: 0.54 0.55 0.58 0.46 0.48 uV  
#1 @ 20mA: 0.44 0.35 0.38 0.36 0.33 uV  
#2 @ 1mA: 0.42 0.43 0.46 0.48 0.41 uV (Vr = 9.84 V)  
#2 @ 5mA: 0.40 0.35 0.35 0.37 0.29 uV (Vr = 9.89 V)  
#2 @ 20mA: 0.34 0.33 0.31 0.30 0.31 uV (Vr = 9.94 V)

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#1 @ 1mA:  
#1 @ 5mA:  
#1 @ 20mA:  
#2 @ 1mA:  
#2 @ 5mA:  
#2 @ 20mA: