T040179-00-K Shadow-sensor study

This report covers work to-date on : -

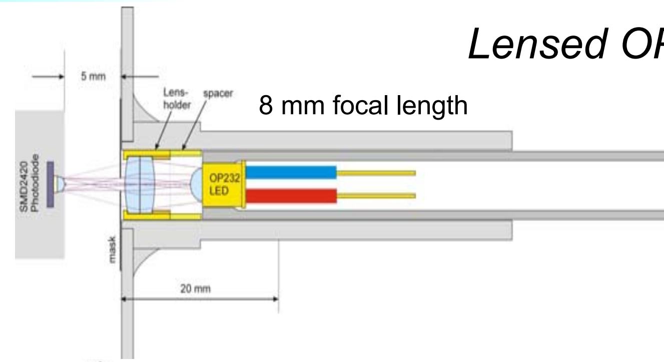
- Shadow-sensor comparative performances—using 3 different optical geometries for the infrared LED.
- Vacuum compatibility of the OP232 infrared LED (from *Optek Technology, Inc*.).
- Results to-date of the reliability tests being run on 24 × OP232 LEDs
  - now tested for over 472 hours.
- Results from the recently constructed *Howland* current-sink, used in conjunction with the OP232 LED.
- Ongoing work
  - ball lens
  - glass light-guide
  - optical fibre stack

N.A. Lockerbie

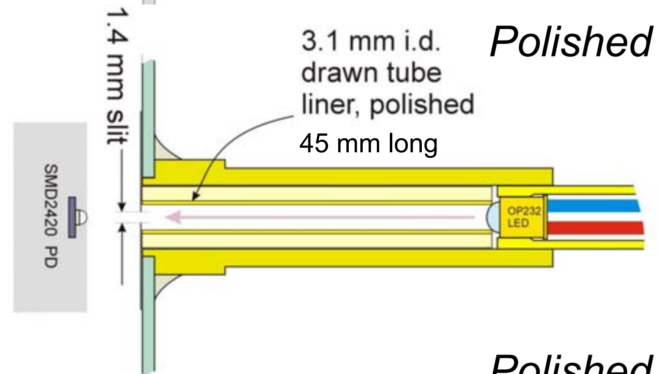
Comparative performance of 3 optical geometries

Displacement Sensitivity ($\times 10^{-10}$ m/rt-Hz)	Span (mm)	Relative PD signal (Arbitrary units)
0.99	0.7	3.4
1.14	0.7	1.1
1.00	0.9	1.0

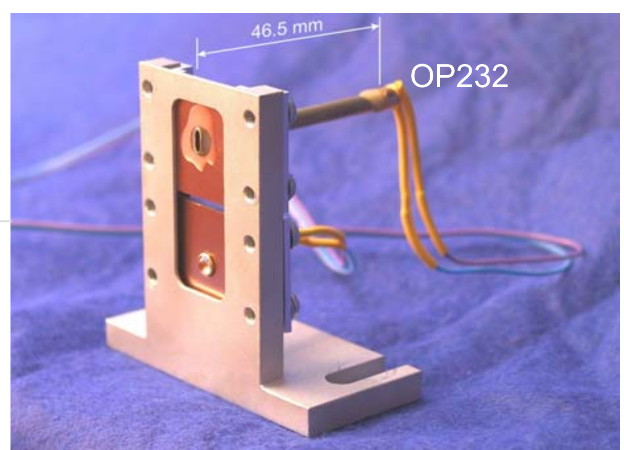
Lensed OP232 + mask



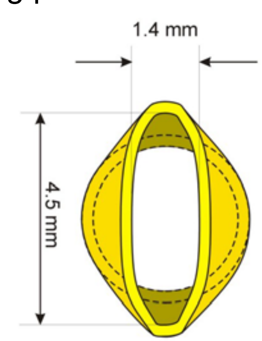
Polished tube + mask



Polished crimped tube



View of flattened end of 3.1 mm i.d. × 46.5 mm long polished brass tube.



The SMD2420 photodiode was the detector in all 3 geometries, with a 5 mm gap for the 3 mm dia. flag. The mask's slit was 1.4 mm × 4.5 mm.

Vacuum compatibility of the OP232 IR LED

Received via e-mail from Dan Jacobs, Reliability Engineer, *TT Electronics*/ *Optek Technology*, 8 September, 2004: -

> "I consulted one of our discrete engineers, Ramon Martinez, who reported:
>
> Both components do use glass. The lens cap is made of glass and the isolated pin feedthrough glass (*sic*). There should be no problem concerning epoxy / alloy degradation since OP232 is an hermetic package."

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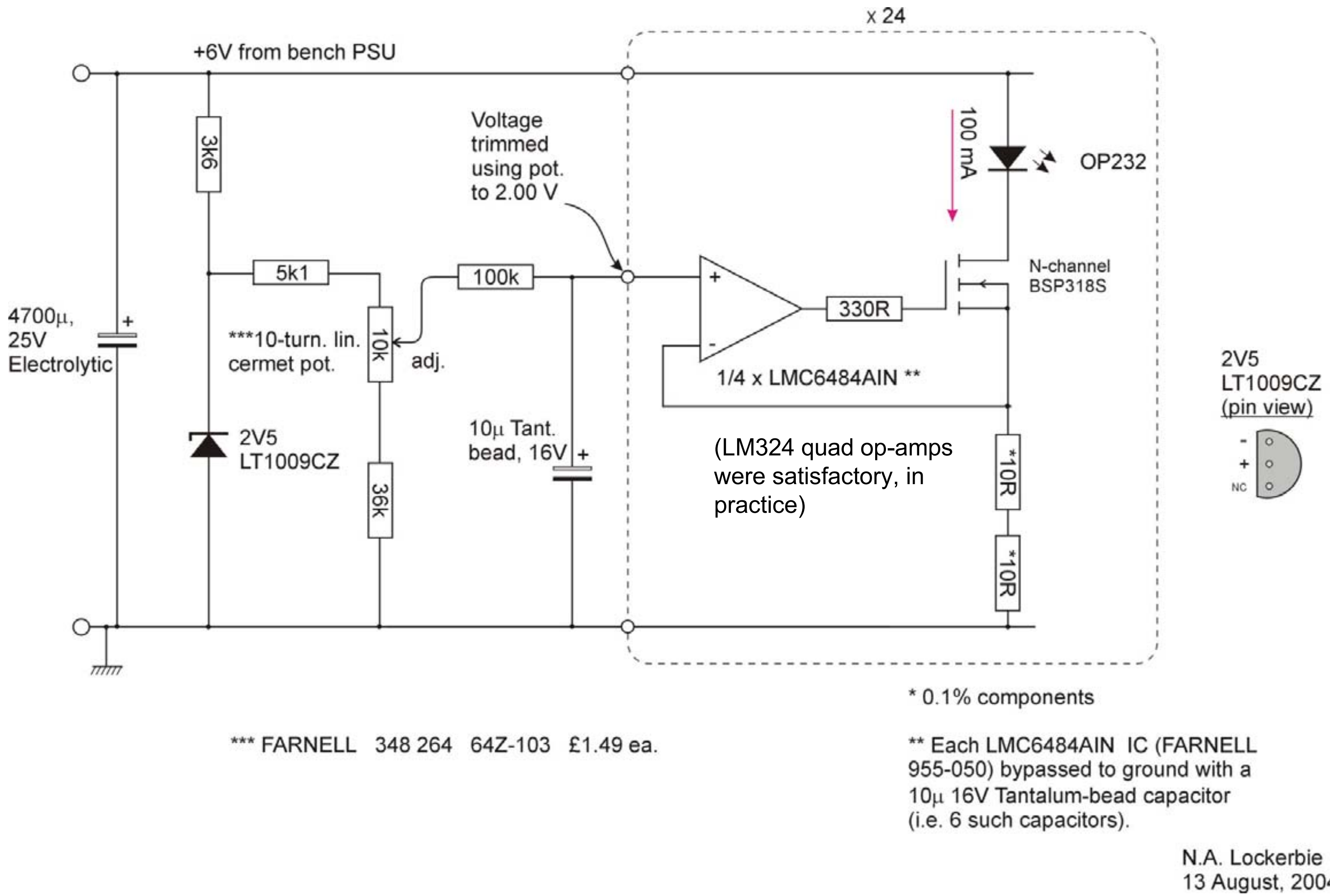
Mean Time To Failure (MTTF) test circuit

- 24 × OP232 infrared LEDs are being run at forward currents of 100 mA.
- Here, the anodes of all the LEDs are connected to the +6 V supply rail.



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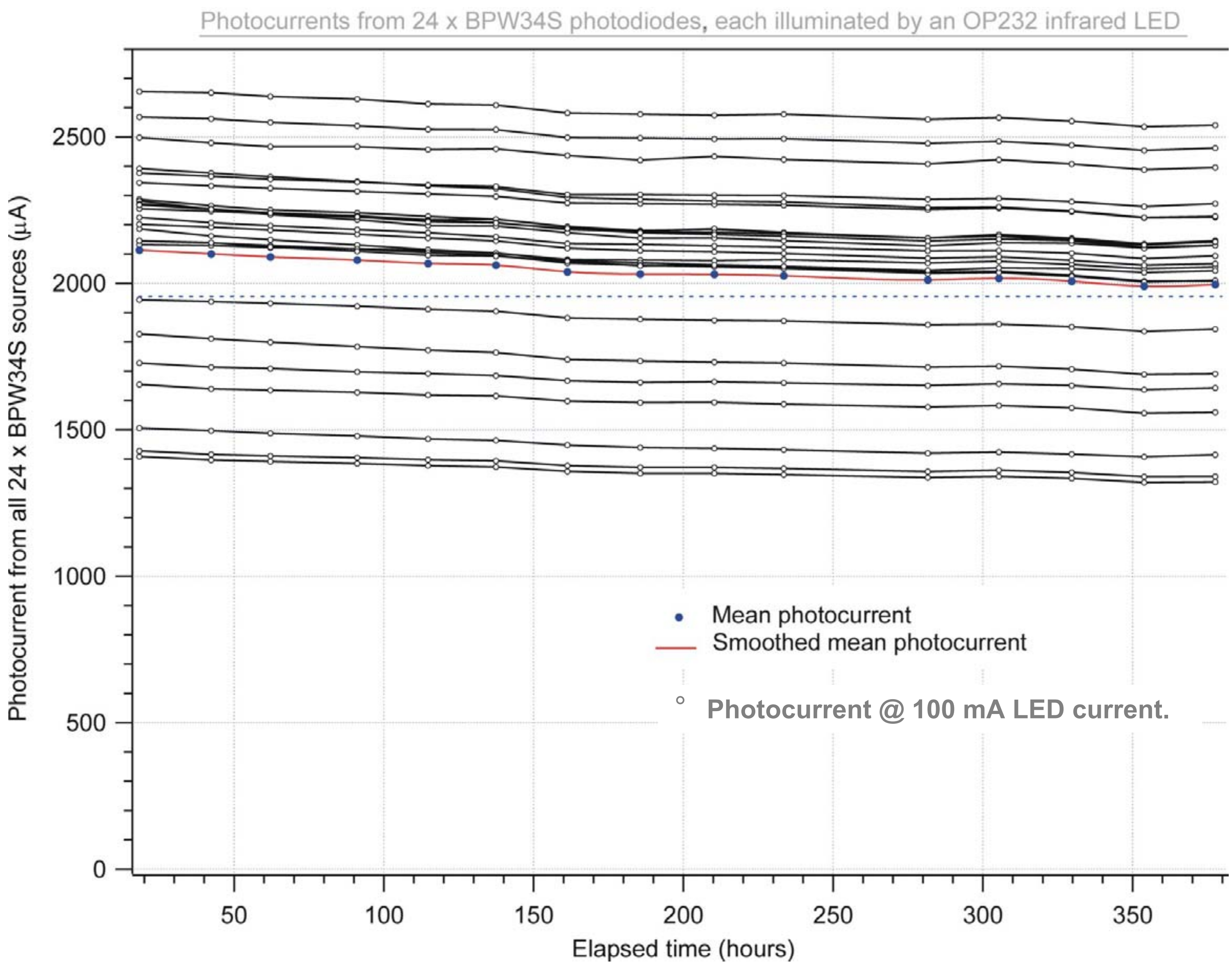
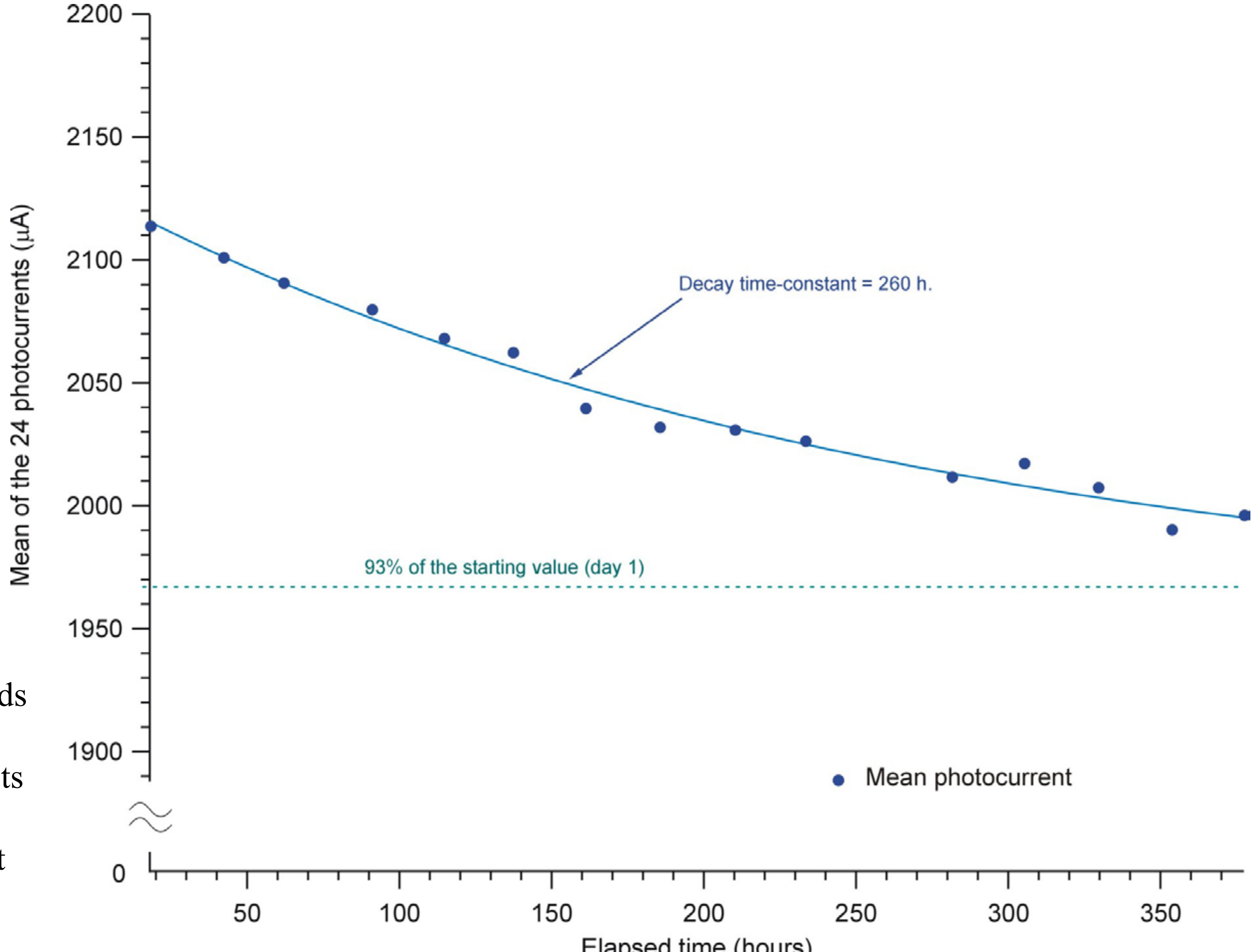
Results from the MTTF tests on the OP232 LED

- The spread in the output intensity of the OP232 is rather less than the expected mean ±50%.
- The ensemble of 24 infrared LEDs has functioned in a consistent fashion.
- None of the LEDs has failed, to-date.



Decay of the mean photocurrent



- An exponential decay towards a non-zero asymptote fits the mean photocurrent data, so far.

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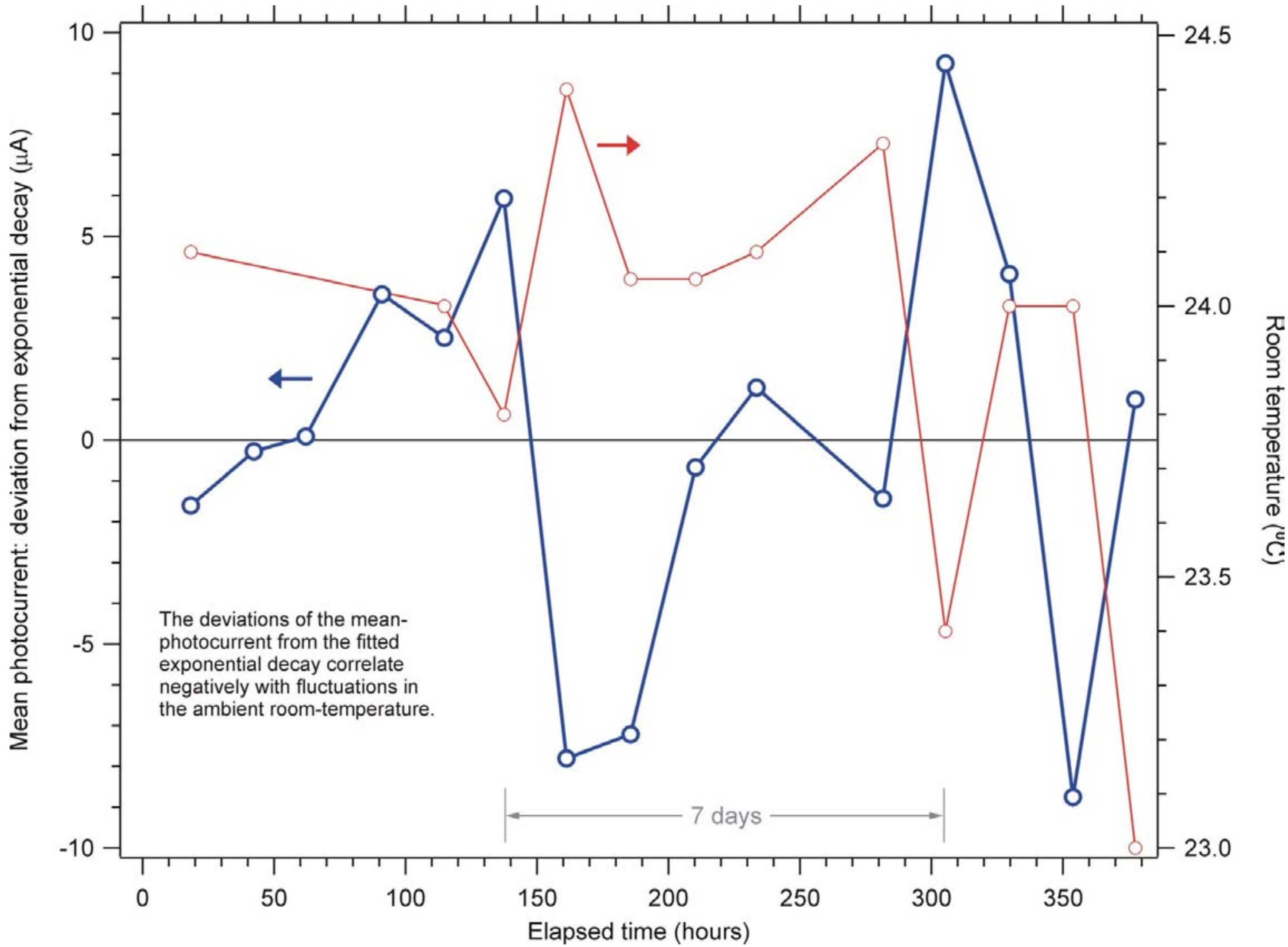
Effect of temperature on the mean photocurrent

- Deviations from the fitted exponential decay are largely due to changes in the ambient temperature.
- From day-to-day these deviations increasingly dominate the apparently slowing decay.
- The ratio of the two standard deviations = 13 μA/ºC.



Howland current-sink development

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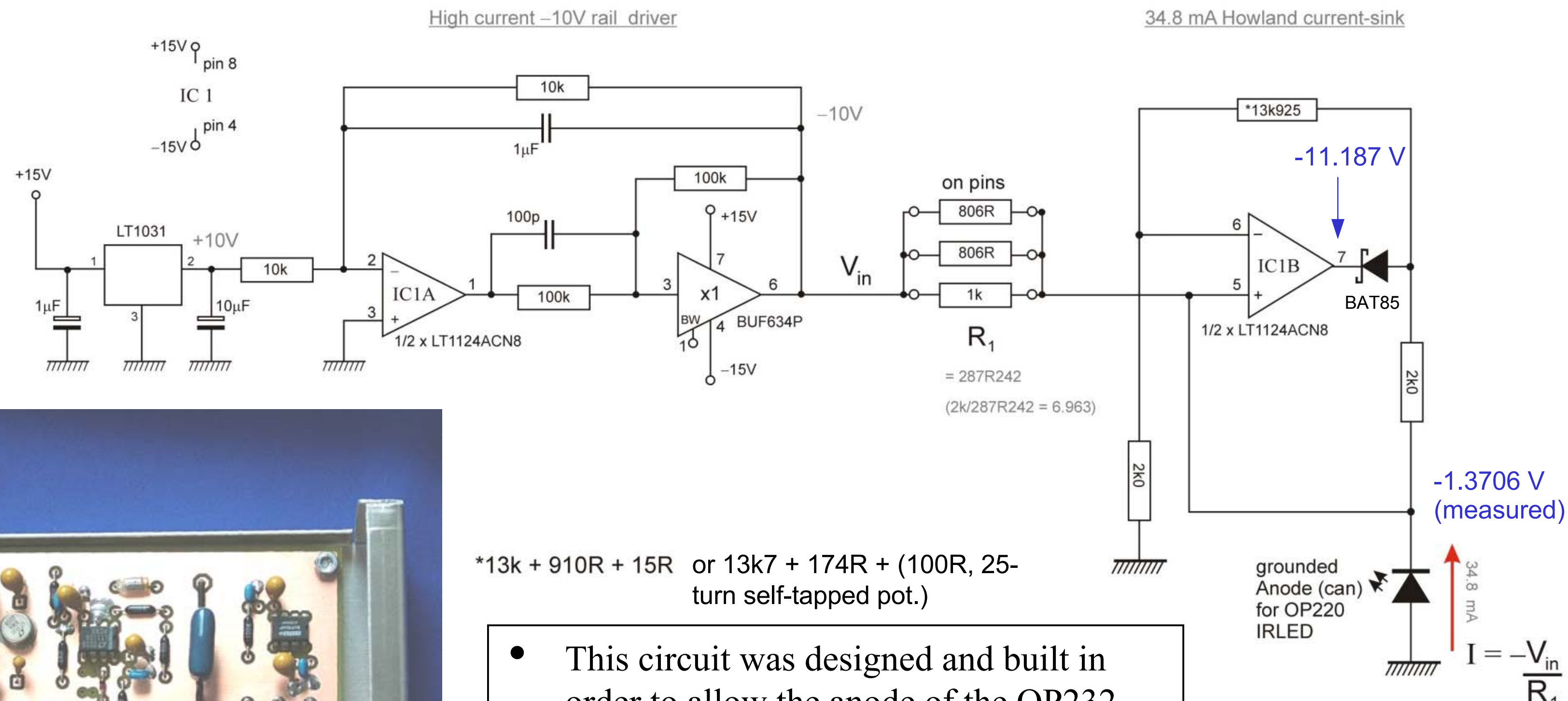
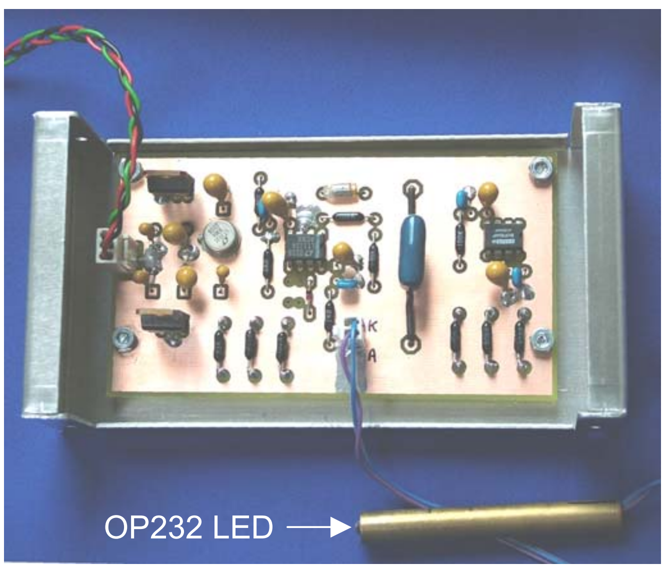
Howland current-sink for grounded-anode LED



*13k + 910R + 15R or 13k7 + 174R + (100R, 25-turn self-tapped pot.)

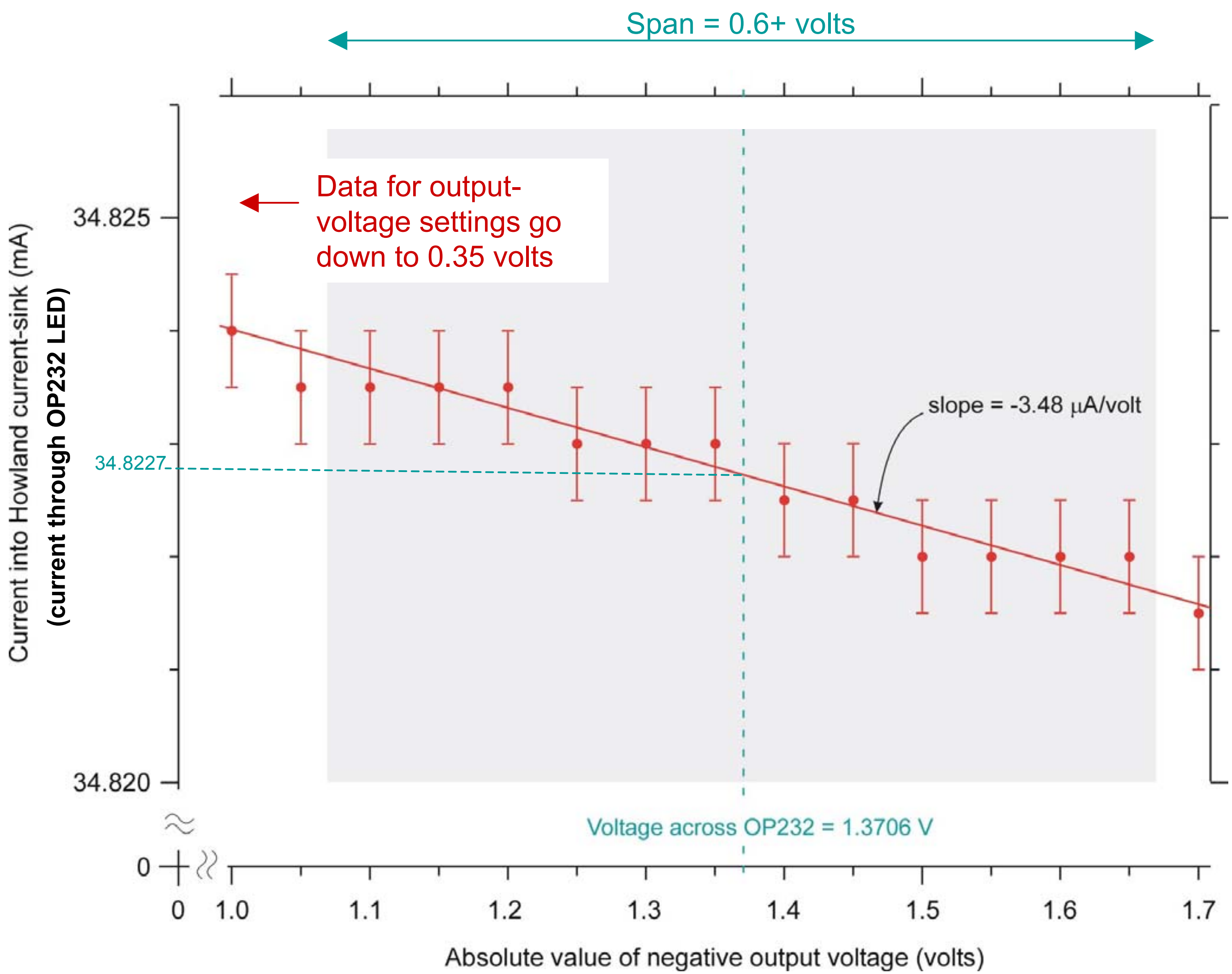


- This circuit was designed and built in order to allow the anode of the OP232 infrared LED (which is connected directly to the device's metal case) to be grounded—for thermal anchorage.
- The target current through the LED was 34.8 mA, as per the LIGO hybrid OSEM.

N.A. Lockerbie
University of Strathclyde
10 September, 2004

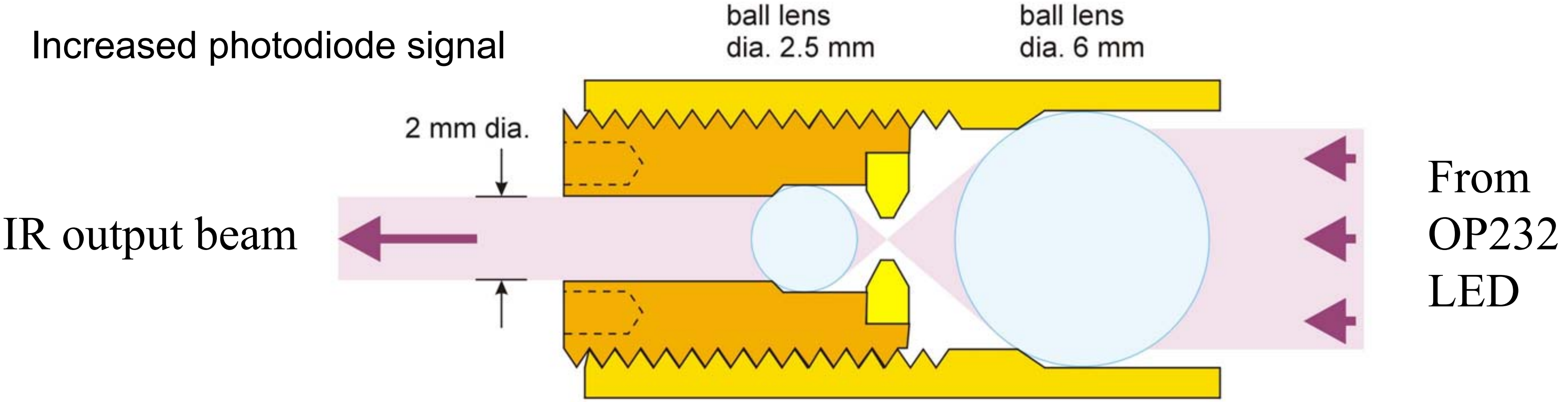
Performance of the Howland current-sink

- Here, a temperature-induced change of ±10 mV in the forward voltage of the OP232 infrared LED, i.e., |ΔT| = 3.2 ºC, would alter the current through the LED by ∓1 ppm.
- This is significantly lower than the 5 ppm/ºC output drift of the LT1031 voltage reference, used here to regulate the current through the LED (as in the Satellite electronics for the LIGO hybrid OSEM).



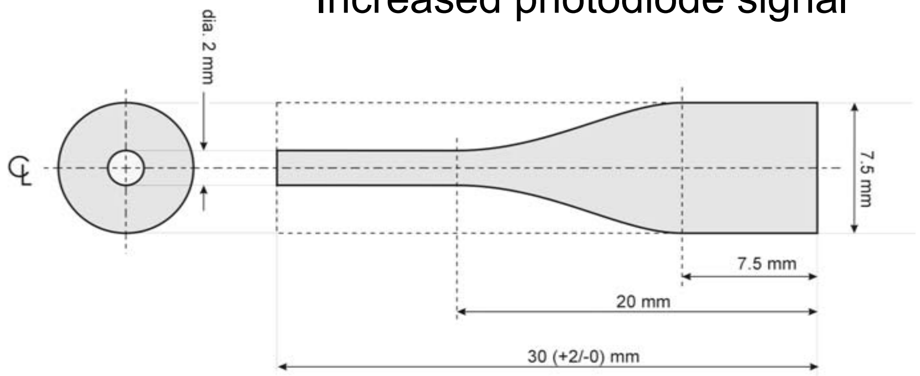
Ball-lens assembly

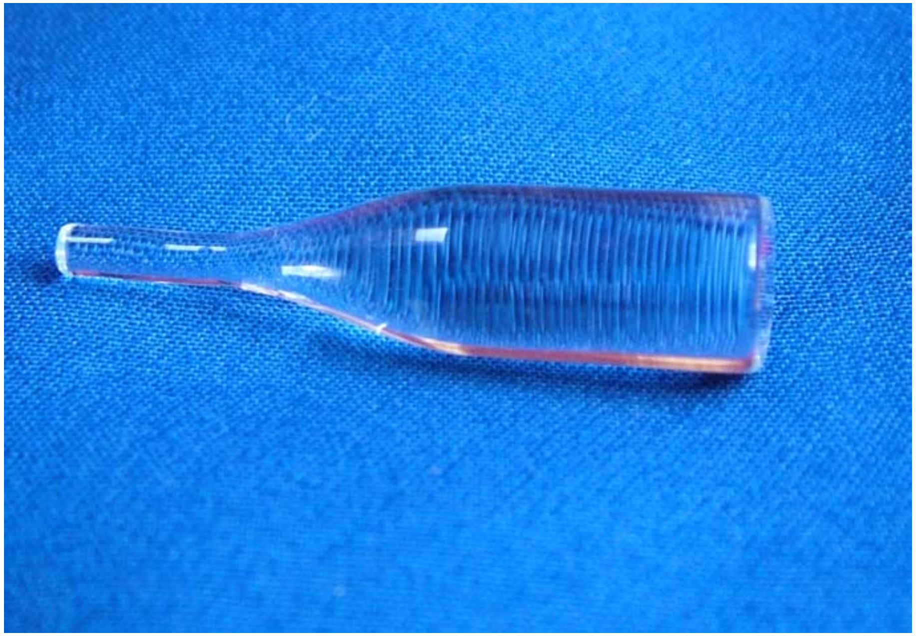
Increased photodiode signal



Glass light-guide/optical fibre stack

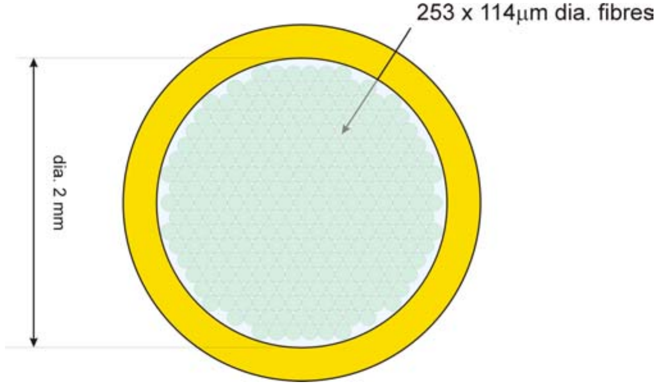
Increased photodiode signal

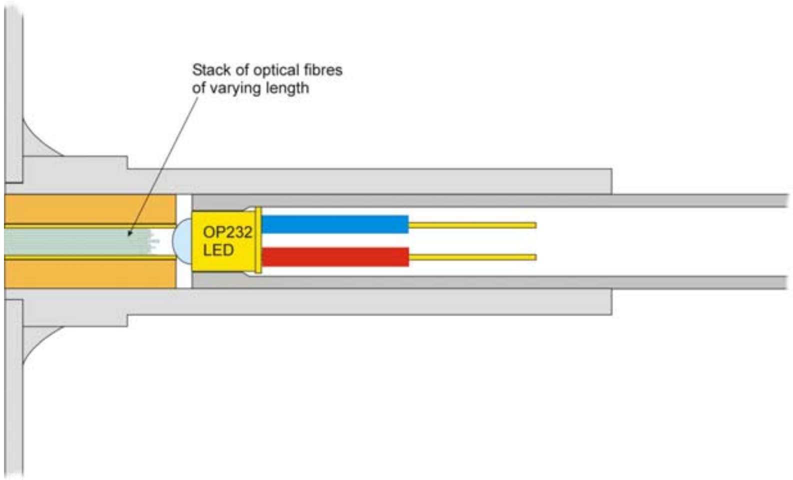




Randomised phase

Reduced low-frequency noise ?





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Conclusions: 1

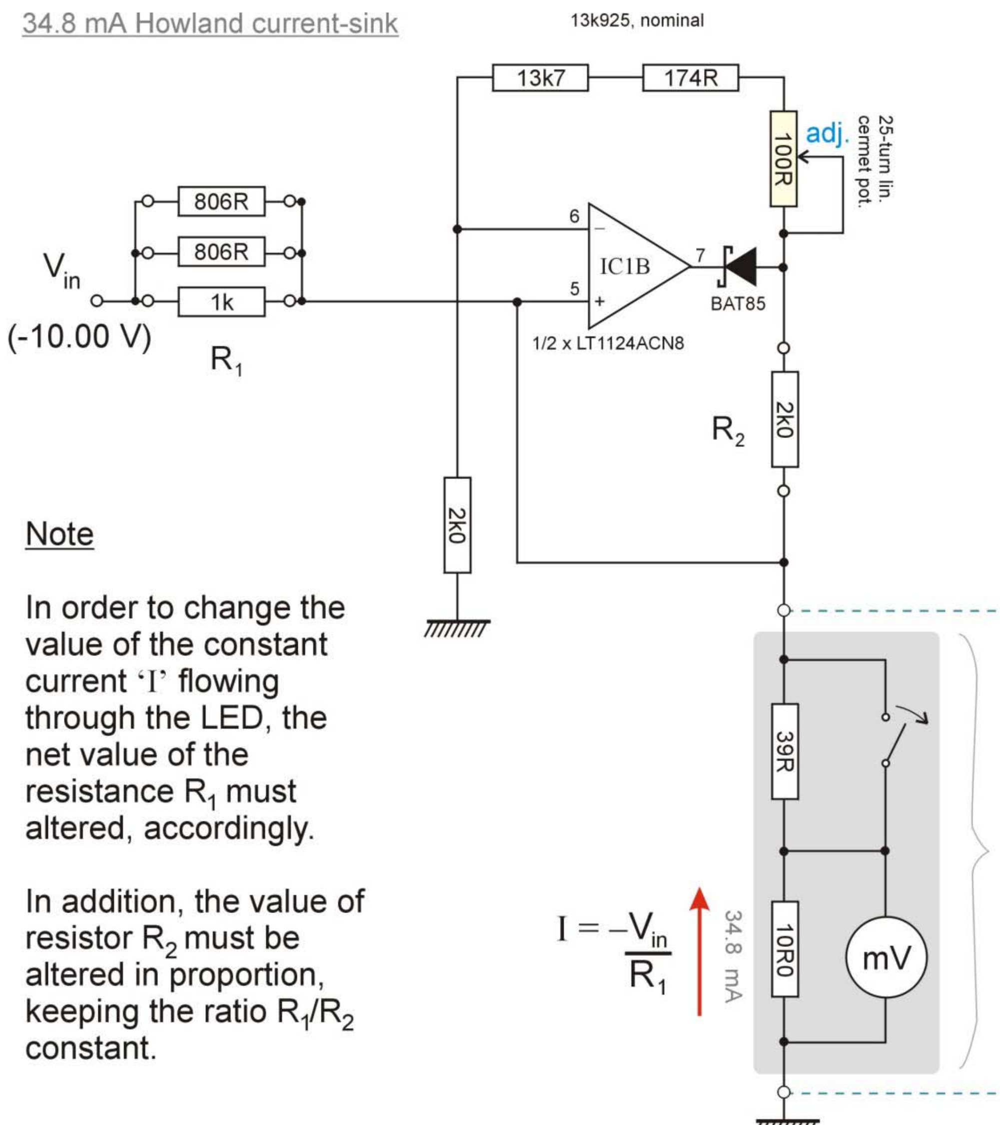
- The polished, crimped, light-guide gave the best shadow-sensor performance, overall. The lensed OP232 infrared LED was dimensionally the most compact.
- The OP232 LED from *Optek Technology Inc*. seems to have no vacuum compatibility issues.
- The infrared output intensity of all 24 of the OP232 LEDs has decreased slowly with time: none has failed, so far.
- Indeed, the mean intensity now seems to be tending towards a final level currently in the region of 93% of the 'day 1' value. However, the decay time-constant is poorly determined at present, and a longer time-constant would imply a (perhaps significantly) lower asymptotic limit.
  - A χ^2 test on the mean photocurrent does not support an additional linear decrease of the mean intensity over time; but, once again, more data will need to be gathered over a significantly longer period before such a possibility can be ruled out.
- The known temperature sensitivity of infrared LED output has been observed here at the level of 6 parts per thousand for a 1 ºC change in the ambient temperature.
  - Half the published value for 100 mA pulsed operation of the OP232.

Conclusions: 2

- The *Howland* current-sink has worked very satisfactorily, using standard 0.1% resistors. Its performance could be improved by adding a 100Ω multi-turn cermet potentiometer, connected as a variable resistor, as part of the 13k925 feedback chain.
  - Improved balancing the current-source would be a simple procedure, as indicated in the Appendix to this report.

Appendix: optimising the Howland current-sink

Two-step optimisation procedure



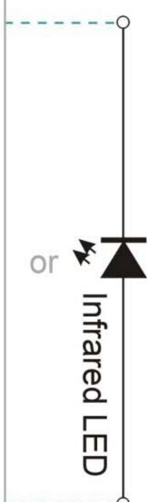
The adjacent test circuit is connected in place of the LED.

Then, measure the voltage across the 10R0 resistor, i.e., the current through the resistor: -

1. with the switch closed. This is a necessary check, anyway.

2. Open the switch, and adjust the 100R pot. for the same voltage.

The millivoltmeter must have 0.01 mV precision at, e.g., 348 mV.



Note

In order to change the value of the constant current ‘I’ flowing through the LED, the net value of the resistance R_1 must altered, accordingly.

In addition, the value of resistor R_2 must be altered in proportion, keeping the ratio R_1/R_2 constant.