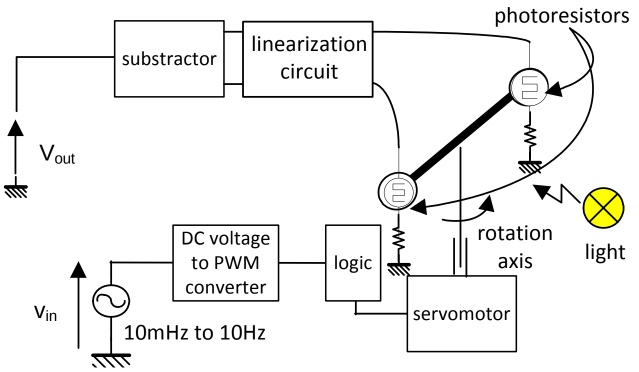

Figure 23: Open loop dynamic characterisation schematic

However, practical open loop response is extremely difficult to measure because of the ultra-slow motion of hobbyist servo (working frequencies less than one Hz) and output voltage low level. The result is given in figure 24 where a realistic +/-5% error margin is indicated.

Without linearization, open and closed loop gain depends on flux F, as described in [5].

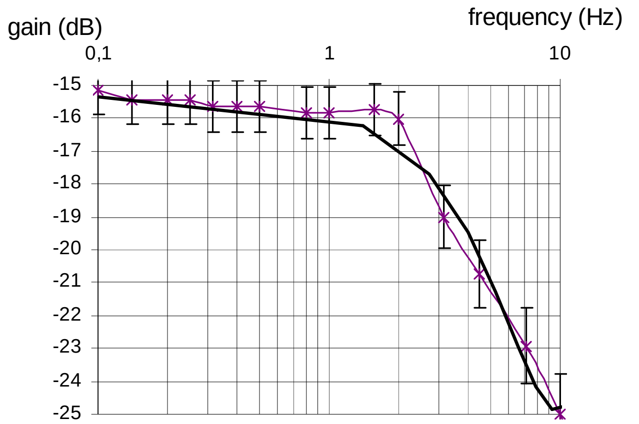

Figure 24: Experimental AC open loop gain V_{out}/v_{in}

Here, we checked for 3 different light intensities 500, 1000 and 2000 lux), that loop gain did not change anymore. Thus, efficiency of linearization is proved.
Finally, loop correction has been adjusted to reduce the static angle error at less than 5° which is enough to check the tracking without any oscillation risk. And the system follows correctly the bubble light.

8. Conclusion

A simple but clever analogue linearization COTS circuit has been designed to linearize the LDR response used in a light tracking small scale system.
Since it has been successfully experimented, it can be used in association with LDR for various small rolling or walking robots applications. However, it does not suppress the necessary preliminary sorting and matching of LDR due to their extremely scattered specifications. In some cases, LDR could be advantageously replaced by infrared sensors (for example SHARP GP2Y0xxxx series) which have an almost hyperbolic 'voltage to distance' well matched response. In this situation associating the circuit described in 3.2 could be enough.

References:

[1] Ph. Dondon, J.M Micouleau, G. Leroyer, Improving student's motivation for sensors and actuators courses : " a multi thematic mini rolling robot design project" *WSEAS Trans. on Advances in ENGINEERING EDUCATION* issue 5 Vol 3 May 2006, ISSN 1790 1979 p 388
[2] U.A Arefin, Md.H Iqbal, M.Jahan Design & Implementation of Light Following Robot Technical report Northern university Bangladesh, March 2014
[3]An Intelligent Line Follower Using Ldr Sensor A. Hannan, M.A. J. Bin Bakkre, Md.S. Hossain, R. Chandra Ray, *American Journal of Engineering Research*, Vol.4,Issue11, pp.92-102, 2015
[4] M. Rubenstein, B.Cimino, R.Nagpal, J.Werfeld, AERobot: An affordable one-robot-per-student system for early robotics education, Int. Conf. on Robotics and Automation (ICRA), IEEE 26-30 May 2015 Seattle, WA, USA
[5] Ph. Dondon, L.Miron, Study of a small scale solar tracking system for a small scale greenhouse model. Int. conf. EE'14, 26-28 juin 2014 Brasov (Romania)
[6] Ph. Dondon, L. Miron, "Effect of Light Dependant Resistor mismatching and impact of non-linearity in a small scale solar tracking system. " int conf AFASES, 28-29 May 2015 Brasov (Romania)
[7] MPY100 multiplier data sheet Burr Brown
[8] Analog device multiplier application guide, Web site: http://www.analog.com/media/en/training-seminars/design-handbooks/ADI_Multiplier_Applications_Guide.pdf
[9] Y. Chen Wong, William E. Ott, *FUNCTION CIRCUITS-Design and applications*, Burr-Brown/McGraw Hill book, ISBN-10: 007071570X.
[10] B.M. Wilamowski, VLSI analog multiplier/divider circuit Proc.. International Symposium ISIE '98. IEEE 7-10 July 1998 Pretoria, South Africa, South Africa
[11] AD633 multiplier data sheet, Web site http://www.analog.com/media/en/technical-documentation/data-sheets/AD633.pdf
[12] G. Asch, Les capteurs en instrumentation industrielle,7ème, *Ed. Dunod, L'Usine Nouvelle*, 2010