Spectrophotometric Pulse Oximetry with a Buried Quad Junction Photodetector

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Summary:

Pulse oximetry is a technique for the noninvasive estimation of the arterial blood oxygen saturation, or S_PO_2, which is an essential parameter to monitor in intensive care units and even in sleep disorder. S_PO_2 is a major indicator of a patient's cardio-respiratory status since it provides the percentage of hemoglobin binding oxygen.

In order to estimate the arterial blood oxygen saturation, two leds at different wavelengths (usually 660 nm and 940 nm) are lit alternatively through a well perfused tissue such as a finger or earlobe and light transmitted is measured at the opposite side. Light is absorbed and scattered by all tissues in the light path such as: nails, skin, bone, venous and arterial blood. Since arterial blood is of a pulsatile nature due to the heart's beating, the resulting optic path changes with time, as arteries expand and contract during systole and diastole respectively. That means that light transmitted will have a periodic form, so an AC and DC components can be distinguished.

The arterial oxygen saturation is calculated from the difference in absorption between the two selected wavelengths, as deoxygenated blood absorbs more light at 660 nm than oxygenated blood and at 940 nm oxygenated blood absorbs more light than deoxygenated blood. These differences in absorption come from the fact that oxygenated blood and deoxygenated blood have different absorption spectrums. Knowing this, an empirical relationship can be established in order to estimate the percentage of both by using the ratio of the AC and DC components for each wavelength. But this technique has some limitations, as some factors can modify the expected AC/DC relationship when some substances (such as nail polish [1] or high amounts of melanin in dark skin [2]) not present during the calibration of the oximeter are present in the patient's finger. The ageing process of leds can also shift their peak wavelength emission and produce errors in the estimation of up to 7% [3].

In this work we propose to estimate the arterial blood oxygen saturation with a single led by using a Buried Quad Junction photodetector, or BQJ. Each junction of the BQJ has a different absorption spectrum and are all linearly dependent. So, an incident beam at a given wavelength, creates a unique and specific current distribution using normalized outputs of the BQJ. With this feature, we can trace the spectral changes in the resulting oxygenated and deoxygenated blood mixture when lighting with a single led. This could improve precision as some limitations associated with the measuring principle itself could be overcome.

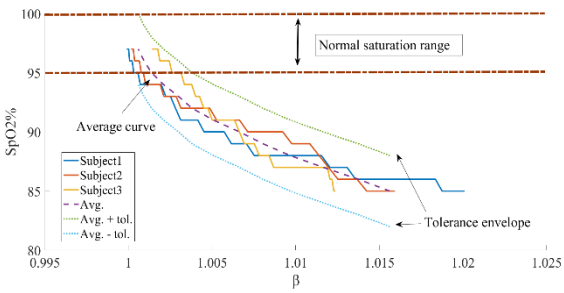

Figure 1. Relationship between two of the BQJ's junctions output ratios and a change in arterial blood oxygen saturation.

Additionally, since the change in the spectral changes can be seen for the AC (arterial) and DC (venous) components separately, an estimation of the venous oxygen saturation could also be estimated. To date, there is no accepted method for measuring venous oxygen saturation optically.

References:

[1] C. Coté, E. Goldstein, W. Fuchsman and D. Hoaglin, "The Effect of Nail Polish on Pulse Oximetry", Anesthesia & Analgesia, vol. 67, no. 7, pp. 683-686, 1988

[2] J. Feiner, J. Severinghaus and P. Bickler, "Dark Skin Decreases the Accuracy of Pulse Oximeters at Low Oxygen Saturation: The Effects of Oximeter Probe Type and Gender", Anesthesia & Analgesia, vol. 105, no., pp. S18-S23, 2007

[3] Q. Milner and G. Mathews, "An assessment of the accuracy of pulse oximeters", Anaesthesia, vol. 67, no. 4, pp. 396-401, 2012