**NIR（近红外）无创血糖检测**

设计分析

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1. 总体描述

## 项目背景

糖尿病患者需要不断监测血糖浓度，目前绝大部分的血糖监测仪进行测量时需要采集指血，造成疼痛和不便，而且要使用新的测试纸，增加了设备使用成本。并且，要确定糖尿病患者最合适的胰岛素剂量需要经常或持续监测血糖，目前的血糖仪无法满足这一要求。NIR进行无创血糖检测是解决这一难题的潜在方法。

## 血糖研究现状

目前关于非侵入式血糖检测方式的研究非常多，有超声、电磁感应、近红外、中红外光谱等数十种新技术，每年发表的文献数目增长迅速[1]。

利用NIR 进行无创血糖检测的想法1993年提出，基于的假设是血糖浓度影响红外光在组织中衰减和反射的系数，因此通过检测光的衰减可以反推出血糖浓度：



但是，虽然1993年提出设想，但2014年来的相关文献里几乎都提到NIR是”most promising techniques for blood glucose noninvasive measurement “，间接说明NIR目前还处于科学研究阶段，离真正商业化具有一定距离。从基于关键词(blood glucose) AND ("NIR" OR "near\*infrared\*"OR"Near-infrared spectroscopy")搜索的文献来看，NIR无创血糖测量研究大都是构想、算法等基础理论问题，其有效性结论也大都基于试管实验和理想模型[1-5]。

阻碍NIR 应用于血糖测量的关键因素在于血糖对红外光的吸收系数远小于水对红外光的吸收系数，因此，红外光信号的衰减只有极少部分是由血糖分子吸收的（约为十万分之一），绝大部分被水、组织和其他分子吸收或反射。红外光衰减对水分变化的敏感度远远大于血糖浓度，要从衰减信号中提取出真正由于血糖浓度导致的差异非常困难。此外，该技术测量精度受测试者生化参数如体温、血压、皮肤水分、甘油三酯浓度和白蛋白浓度影响，同时也受环境因素如温度、湿度、气压等因素影响。

2012的综述文章描述该技术的段落摘录如下：

NIR spectroscopy uses a beam of light with wavelength in the range of 750–2500 nm [18–22], which is focussed on the body to estimate glucose concentration in the tissues (1–100 mm deep) by measuring variations in the light intensity due to transmission and reflectance in the tissue. The changes in glucose concentration affect the absorption and scattering coefficients of a tissue. In the NIR band, the absorption coefficient of glucose is low, which is much smaller than that of water due to the large difference in their concentrations. The absorption coefficient and concentration in this

region are such that the glucose signal constitutes about only 1 part in 100,000, the major contribution being due to water. The change in the water signal with temperature over 2 ◦C is equivalent to the entire signal change for glucose in the clinically-relevant range. Therefore, the stronger NIR spectra of water, hemoglobin, proteins and fats overlap with the weak spectral bands ofglucose. This technique has been employed to determine glucose in ear lobe, finger web, finger cuticle, skin of the forearm, lip mucosa, oral mucosa, tongue, nasal septum, cheek and arm. The NIR measurements on the finger correlated with blood glucose but were clinically unacceptable due to insufficient accuracy. However, the NIR measurements of the inner lip correlated well with a time lag of few minutes. 20 S.K. Vashist / Analytica Chimica Acta 750 (2012) 16–27 The technique has serious limitations as it is affected by physicochemical parameters such as changes in body temperature, blood pressure, skin hydration, and concentrations of triglyceride and albumin. Moreover, it is sensitive to environmental variations in temperature, humidity, atmospheric pressure and carbon dioxide content. The measurements are also affected by the thickness and thermal properties of the skin [23–25], and the disease states such as hyperglycaemia and hyperinsulinemia [26–28]. The NIR measurements determine the overall glucose concentration in the blood and the interstitial fluid in the tissues. But it is difficult to

segregate the contribution of NIR signal due to the glucose concentration in blood or interstitial fluid.

产品方面，文献说明迄今为止得到FDA认可的NIR 血糖测量设备只有OrSense NBM-200G 但从该公司官网上并没有找到类似说明。

<http://www.orsense.com/product.php?ID=39>

## 血氧测量

血氧检测原理可参考：

<http://www.21ic.com/app/med/201203/108867.htm>

<http://wenku.baidu.com/link?url=32ABfSTmx2gDjU-YWb9MzI2Js4Y2lt9qGf-Fug2rkbtkLFXpSu7P1gTX21VoZ3qbRs_lSbJiK2bztRvDTvMIObArw3UiglnBQVwuUe_yfjO>

## 技术和研究风险评估

基于现有文献调研情况表明，NIR无创测量血还是一个不成熟的技术，处于科学研究和探索阶段，已有的尝试证实其精度太差尚无法临床使用[1]。如1.2中所述，在光衰减中，血氧分子吸收占总吸收比例太低是导致该技术推广的根本因素，同时该技术测量血糖时受众多生化和环境因素影响，需要采集众多实验数据及复杂的校正算法。

文献《Non-invasive blood glucose monitoring using near-infrared spectroscopy》提到”Pulse Oximetry was used to measure blood oxygen. Pulse Oximetry uses Red and Infrared (IR) light to distinguish between Hemoglobin and Oxy-Hemoglobin in the blood, on which further processing is applied to get the oxygen saturation [2]”，~~但是相应参考文献并没有涉及相似内容，即如何利用绿光测量耳垂厚度，红光和IR测量血氧这个两个步骤也是值得商榷的。~~

从现有研究现状和产品现状来讲，依据文献文献《Non-invasive blood glucose monitoring using near-infrared spectroscopy》研发NIR 无创血糖检测产品存在很大不确定性。

## 文档范围

本文档包括产品硬件设计文档、软件设计文档，适合的读者对象为研发团队、商务团队。

## 参考文献

1. Vashist S K. Non-invasive glucose monitoring technology in diabetes management: A review[J]. Analytica chimica acta, 2012, 750: 16-27.
2. Yadav J, Rani A, Singh V, et al. Near-infrared LED based non-invasive blood glucose sensor[C]//Signal Processing and Integrated Networks (SPIN), 2014 International Conference on. IEEE, 2014: 591-594.
3. Vashist S K. Non-invasive glucose monitoring technology in diabetes management: A review[J]. Analytica chimica acta, 2012, 750: 16-27.
4. Li Z, Li G, Yan W J, et al. Classification of diabetes and measurement of blood glucose concentration noninvasively using near infrared spectroscopy[J]. Infrared Physics & Technology, 2014, 67: 574-582.
5. Ramasahayam S, Koppuravuri S H, Arora L, et al. Noninvasive Blood Glucose Sensing Using Near Infra-Red Spectroscopy and Artificial Neural Networks Based on Inverse Delayed Function Model of Neuron[J]. Journal of medical systems, 2015, 39(1): 1-15.

## 术语与缩写解释

1. 功能描述

## 总体描述

项目实现在耳垂处实时检测血糖含量，并通过BLE将血糖、血氧等参数传递至智能手机端。

1. 硬件设计分析

## 各部分功能描述

系统硬件框图如下所示，采用Psoc 4单芯片外加LED光源方案实现，BLE通信，光源驱动，模拟信号放大，采集均由Psoc 4芯片完成。Psoc 4集成BLE 组件，内置通用轨到轨放大器及12位SAR ADC。



其中，各模块简要说明如下：

1. PWM

Psoc 4输出5路PWM驱动2个NIR，1个IR，1个RED和1个GREEN。由于PWM占空比与光源波长相关，在试验阶段要求PWM占空比可配置。

1. ADC

采用PSoc 4内置12bit ADC，ADC前端接内置的通用放大器

1. PGA

PGA需要外接阻容元件配置放大倍数等参数

UART

1. DEBUG，PWM占空比配置，以及输出ADC采集数据
2. BLE

将数据传至手机等终端设备。

## 引脚说明

|  |  |  |
| --- | --- | --- |
| **引脚** | **说明** | **连接** |
| P0.0 | PWM输出，驱动第一个NIR LED | 第一个NIR LED驱动端 |
| P0.1 | PWM输出，驱动第二个NIR LED | 第一个NIR LED驱动端 |
| P0.2 | PWM输出，驱动RED LED | RED LED 驱动端 |
| P0.3 | PWM 输出，驱动IR LED | IR LED 驱动端 |
| P1.6 | PWM输出，驱动GREEN LED | GREEN LED驱动端 |
| P1.0 | 放大器正极输入 | 光接收器输出经过RC滤波后接入该端 |
| P1.1 | 放大器负极输入 | 反馈电阻接该端 |
| P1.2 | 放大器输出端 |  |
| P3.0 | AD 采集输入端 | 放大器输出接入该端 |

1. 软件设计分析

## 实验阶段程序功能

1. 实验阶段，程序主要服务于数据的采集，为方便使用，通过串口将数据传至PC，由PC端进行数据信号处理。
2. 程序尽可能高速的采集光衰减信号
3. 程序流程如下：



配置格式：

通信格式：115200,8bit,0,1stop

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Byte0 | Byte1 | Byte2 | Byte3 | Byte4 |
| 0xaa  引导码 | 0xee  引导码 | 0xxx  0x01：GREEN,测试耳垂厚度  0x02:RED 测试血氧  0x03:IR 测试血氧  0x04：NIR 测试血糖 | 0X00;  0—99:pwm驱动占空比 | Crc |