# Implementation of Continuous Wearable Low Power Blood Glucose Level Detection using GSR Sensor

Wira Hidayat bin Mohd Saad[1], Muhd. Shah Jehan Abd. Razak[2], Tan Yun Sheng[1], Nurul Akmal binti Abd Salam[1], Fauziyah bte Salehuddin[1], Wong Yan Chiew[1]

[1]*Faculty of Electronic and Computer Engineering, Universiti Teknikal Malaysia Melaka, Durian Tunggal, Melaka, Malaysia.*

[2]*Faculty of Plantation and Agrotechnology, Universiti Teknologi Mara Melaka (Jasin Campus), Merlimau, Melaka, Malaysia*

*wira_yugi@utem.edu.my*

***Abstract*—Diabetes Mellitus is one of the most common life-threatening diseases in the world. The aim of this project is to implement a low power wearable system for continuously monitoring the glucose level in human blood by using GSR sensor. The development of non-invasive blood glucose level detector is desired to replace the invasive method which is inconvenient and expensive. This project is successfully detected by the GSR value and establishing a correlation between GSR and the blood glucose level. It is clearly demonstrated that GSR can be useful in assisting in determining the blood glucose level as an alternative method for the non-invasive approach. A correlation of 65.73% was found from the result and a threshold of (+-2V) for GSR data and it is identified for the end user to alert their blood glucose level. However, there are some factors such as dynamic movement, temperature and calories burnt might affect the accuracy and precision of the prototype.**

***Index Terms*—Diabetes Mellitus, Galvanic Skin Response, Blood Glucose Level, Surface Mount Technology, Bluetooth Low Energy.**

## I. INTRODUCTION

The development of non-invasive blood glucose level detector is desired to replace the invasive method which is inconvenient and expensive. This project is targeted to detect the blood glucose level by using the GSR sensor and to establish a correlation between GSR and the blood glucose level. This project was divided into two parts, which are the hardware implementation and software implementation. For the hardware implementation, it is a conditional circuit between the GSR sensor and human skin conductance to detect the glucose level which contains in sweats. While for software implementation, the Bluno Beetle microprocessor is developed to collect and save the user data. The data collected is then transmitted to the Android application via Bluetooth 4.0. There is a relationship between blood glucose and GSR where it is possible to find the inverse function and from it can calculate the blood glucose level from the GSR voltage.

Diabetes Mellitus is a continuous condition that impacts the human body by reducing the insulin, which conveys glucose into the platelets. According to World Health Organization, over the year 2017, the number of diabetes patient increase by doubling since 1980 to approximately 422 million worldwide [1]. While there are estimated about 3 million diabetes patients in Malaysia and recorded 17.5% of the Malaysian Citizen ages 18 years old and above had the diabetes diseases [1]. Thus, it is very important for these patients to determine their blood glucose level so that they can maintain the insulin level or control their daily glucose intake.

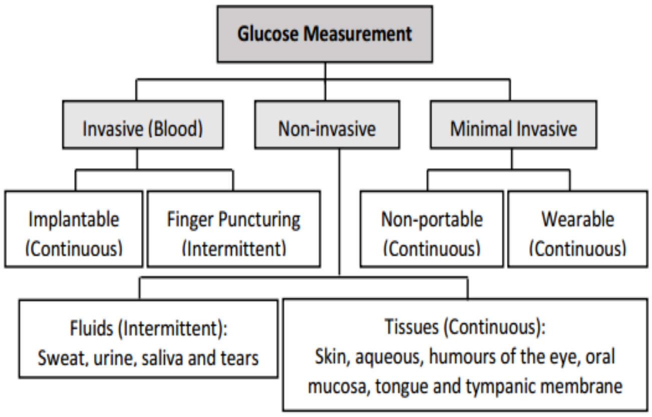


Figure 1: Categories of blood glucose measurement [2]

The galvanic skin response (GSR) is one of the non-invasive methods. Figure 1 shows that under the non-invasive categories, it separates into two major parts which are fluid for intermittent result and tissues for the continuous monitoring result. GSR technique is under tissues part, since it is using the skin. This project aims to create a continuous monitoring non-invasive method for blood glucose level detection. Thus, the tissue studies are more relevant for GSR method. These tissue signals can also be recognized as a physiological signal.

The detection of blood glucose level using GSR is still in its very fundamental stages and the previous studies for the blood glucose level detection are limited. It is very crucial for us to find the correlation between the blood glucose level and the GSR. This study has attempted to overcome the limitation of the common GSR conditional circuit that is relatively bigger in size and no mobility. This is important since the device will be needed to wear all days for data collection.

## II. METHODS

Project design can be divided into two parts, which are the hardware and software implementation. For the hardware implementation, a conditional circuit is being designed to enable the GSR sensor to make communication with human skin conductance which is to detect the glucose level that exists in the sweats [3]. While for the software implementation, the Bluno Beetle microprocessor is developed to collect and store the data. Additionally, it has become a transmission medium for the system to communicate with a smartphone that has an Android Platform Application via Bluetooth 4.0 (BLE). The hardware block diagram of the system is shown in Figure 2 and overall designed flow chart in Figure 3.

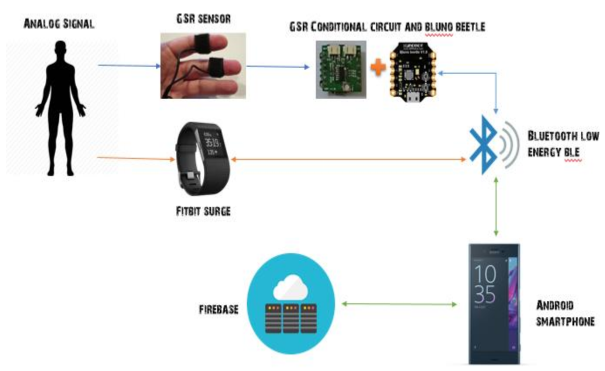


Figure 2: Hardware block diagram

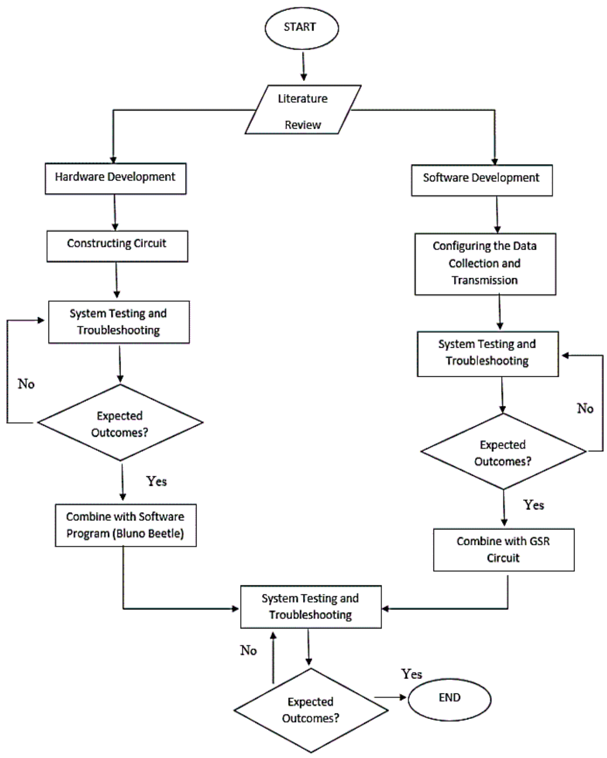


Figure 3: Overall design flowchart of the project

*Phase 1: Design of the Conditional Circuit for GSR*

After choosing the suitable electronic component, a circuit is designed on a breadboard for testing. In this part, the GSR sensor is focused on detecting the glucose level by implementing the low and high pass filter circuit. Then, the circuit is designed in circuit simulation software and then is aching for testing purpose as can be seen in Figure 4. Then, it was fabricated by using SMT component to reduce the size of the conditional circuit as can be seen in Figure 5 to achieve the objective which is continuous wearable devices for the blood glucose monitoring system.

Basically, the GSR Sensor circuit consists of the voltage divider, resistor, capacitor (RC) circuit, and operational amplifier component. The sensor was connected to V+ and V-, with a high-resistance value which is 1 MΩ. This resistor was placed in between V- and one of the sensor electrodes as the voltage value across it is vary based on the body GSR. By using the high value of resistance, it can develop the resistance-voltage curve linear over a wide range of the skin resistances despite producing noise. The RC high-pass filter was used to calibrate a steady baseline since the skin resistance can be varied based on individual conditional. A low-pass RC filter was used to filtering out the high frequency noise that produces from nearby. The op-amplifier is a function to measure the skin resistance and form one of the resistors in the op-amp feedback loop and amplify the voltage.

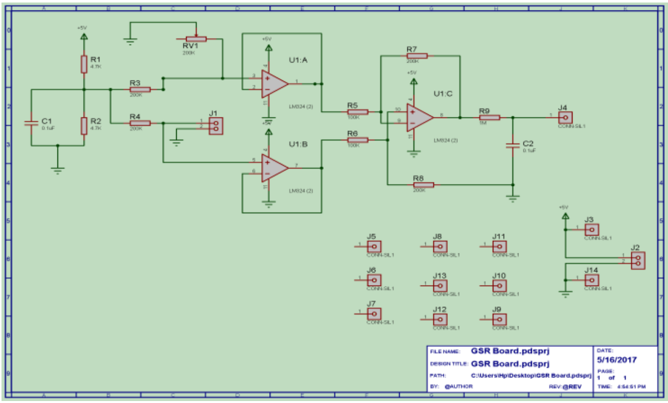

Figure 4: Schematic layout of GSR conditional circuit

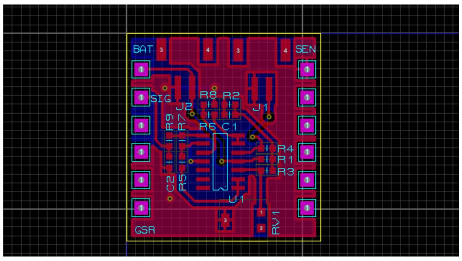


Figure 5: PCB layout circuit in surface mounting technology

*Phase 2: Software Development for Bluno Beetle and Android Application.*

Bluno Beetle is an invention for the wearable electronics devices. It is completely adapted to the coding and using the Arduino IDE application without any extra driver. The relatively compact in size with the V shaped gilded I/O interface, make the conductor wire can be easily screwed on it, making this microprocessor a better choice in the wearable market [4]. Then, an application will be designed with Android Studio [5]. The designed Android application is called “GSR BGL” and it is created to read and store the data from the prototype as can be seen in Figure 6. When a user enters the application, it will check whether the Bluetooth of the host is enabled or not. Then it will connect with the prototype and show the status of the connection. The GSR data are sent to the smartphone for data monitoring and an online real-time database is being implemented for storing the data as shown in Figure 7 [6].


Figure 6: "GSR BGL" Android Application

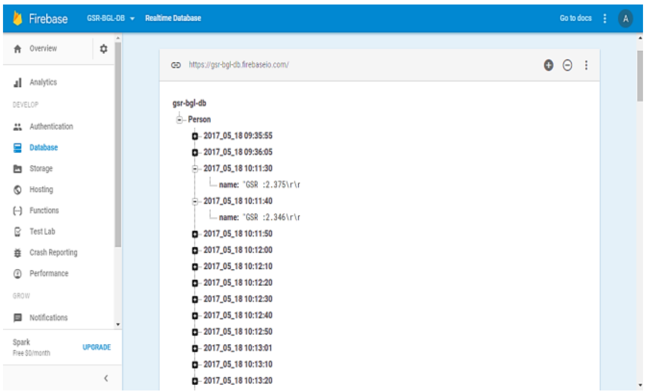


Figure 7: "GSR BGL" cloud database interface

The process flow of the working system is shown in Figure 8. Firstly, the GSR sensor is placed on two fingers to detect the skin conductivity. The signal obtained is in analog form. Then, the GSR conditional circuit will amplify and filter out the unwanted noise. The Bluno Beetle will catch the analog signal and convert the analog signal into a digital signal in every five minutes or at any desired time sample that we intended to set and remapping the signal to display out the GSR value in voltage. Then, it will transmit the data wirelessly via BLE to an Android smartphone. At the same time, the data is also sent to the online database in real-time simultaneously.

## III. Experimental Analysis

### *A. Final Prototype Evaluation*

In order to achieve the objectives of a continuous variable and encourage the end user to continue wearing the devices, optimization of the hardware is needed to be made. It is known that the circuit board can be shrunk into a compact size by using the SMT component. The major advantages of SMT are to implement smaller component so that we can achieve higher component density in the printed circuit boards. Besides that, it does not require the circuit board to be drilled for assembly. In addition, it also provides a better predictable high-frequency performance by reducing the unwanted effects of RF signal due to lower resistance and induction between the connections. Figure 9 shows the comparison of the prototype circuit using comparable component and SMT components.

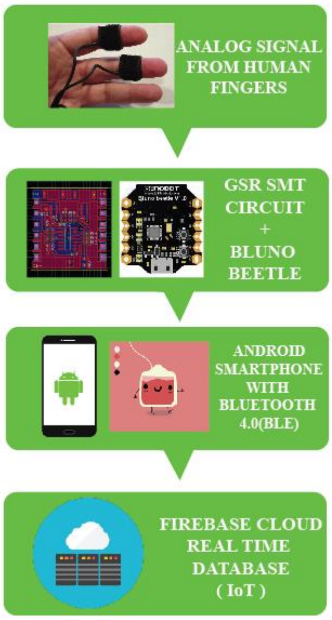


Figure 8: Overall system working flow of a data acquisition

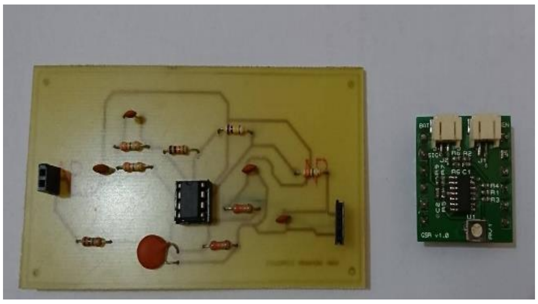

Figure 9: Comparison between initial prototype design (left) and after optimization using SMT component (right)

### *B. Correlation of GSR Data to the blood glucose level*

Since this study is intended to obtain the correlation between the GSR and the blood glucose level. Several experiments carried out simultaneously to assist in the analysis of data and result. Besides that, the experimental subject is also wearing the Fitbit Surge to obtain some of the other data, such as step count, daily food logs, calories burnt and daily activities. These experiments are carried out by following the schedule of twelve hours continuously and at the same time. The experiment is specially customized in this study to find the correlation between GSR values with human blood glucose level. Apart from that, with the aids of the Fitbit Surge, this project is also managed to tabulate some other data that is crucial to assist in this project to identify the correlation between GSR value, glucometer reading, daily food log, daily total food intake, steps count and calories burnt. By combining more different type of data is helping this project to be more informative to predict the threshold or the accuracy of the prototype. The subject is a 24 years old male with BMI readings of 22.22 kg/m$^2$.

Based on Figure 10, the experiment started at 0800 with the GSR reading of 2.654V and the Glucometer reading is 4.9 mmol/L. From 0800 to 1015, there is no food intake and the activity is minimal thus the average GSR data is tabulated at 2.5V. There is a significant drop in GSR Data from 1020 to 1.004V. This is due to the high activities time and increasing in the steps count and calories burnt will influence the reading of the GSR

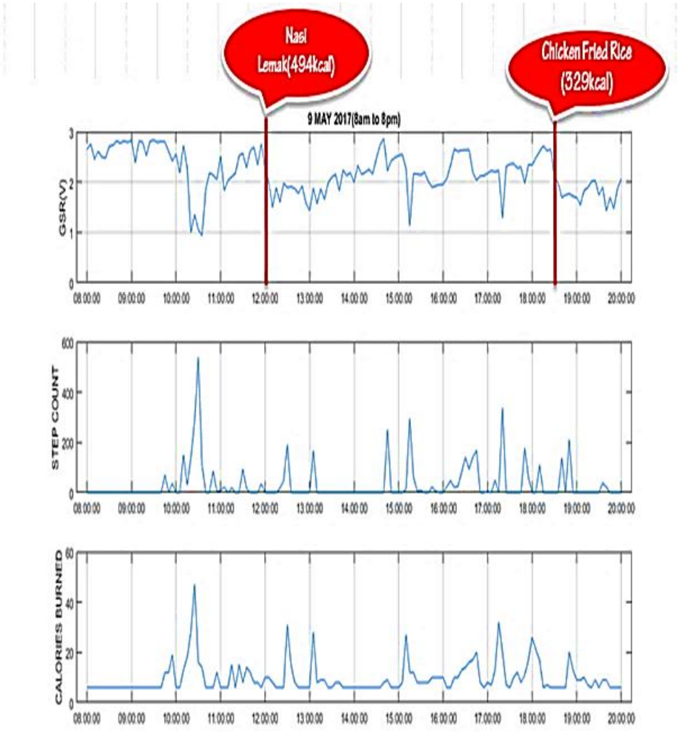


Figure 10: GSR readings, Step Counts and Calories Burned for 12 hours.

.

Another Glucometer reading is taken at 1100 (one hour before having the lunch) and the result is 4.7 mmol/L with GSR Data charted at 2.517V. At 1200 noon, the subject takes his lunch with Nasi Lemak (494 kcal), at 1225, a glucometer test is carried out and the reading is 9.2 mmol/L and the GSR data is charted at 1.975V.

The GSR data from 1210 to 1320 is tabulated at an average range of 1.5V to 1.9V. Thus, the resulting graph shows that the GSR data is inversely proportional to the Glucometer reading.

Then, another glucometer test was carried out in 1435, the result is 5.9mmol/L and GSR data charted at 2.739V. The GSR reading is again dropping dramatically at 1515 to 1.131V due to highly activities in that period with a record of the 294 steps and 27kcal calories burnt per 5 minutes. The fifth test is about 1735 (one hour before dinner) and the result of glucometer reading is 5.4 mmol/L while the GSR data is 2.366V.

At 1830, subject take his dinner with chicken fried rice (329 kcal). The final glucometer test before the experiment is taken at 1900 and the glucometer reading is 8.6 mmol/L while the GSR data is 1.695V. For the period of 1840 to 1950, the GSR data tabulated are also below 2V. This is proven that a threshold of 2V is identified for the user to monitor and aware of their blood glucose level thus, keeping track of their daily activities and diet.

The graph in Figure 11is plotted based on Table 1 shown the differentiation of GSR voltage output before meal taken and after meal taken and from this graph we can see the GSR voltage output is slightly decreased after 30 minutes meal is taken.

Table 1
The GSR voltage output based on the meal taken.

| Meal | Before Meal | After Meal |
|---|---|---|
| Lunch | 2.517V | 1.975V |
| Dinner | 2.366V | 1.695V |

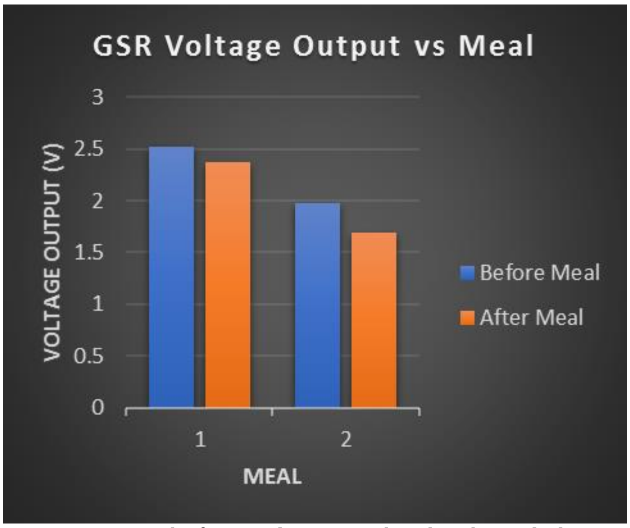


Figure 11: Graph of GSR voltage output based on the meal taken.

The reading taken as in Table 2 is extended for a few days to take several samples of GSR reading and in order to compare those reading with blood glucose reading and plot in Figure 12. From the result that is being tabulated, it shows that the GSR data is inversely proportional to the blood glucose level. The higher the blood glucose level, the lower the value of the GSR data as there are a linear increment and steady baseline in finding the correlation between the GSR reading and blood glucose reading.

Table 2
GSR value versus blood glucose level

| GSR Data (V) | Blood Glucose Level (mmol/L) |
|---|---|
| 2.654 | 4.9 |
| 2.517 | 4.7 |
| 1.975 | 9.2 |
| 2.739 | 5.9 |
| 2.366 | 5.4 |
| 1.695 | 8.6 |
| 2.757 | 4.9 |
| 2.053 | 4.5 |
| 1.862 | 9.3 |
| 2.864 | 5.7 |
| 2.178 | 5.6 |
| 1.569 | 8.9 |
| 2.784 | 5.1 |
| 2.681 | 4.8 |
| 1.783 | 9.3 |
| 2.147 | 5.9 |
| 2.548 | 5.3 |
| 1.587 | 8.7 |

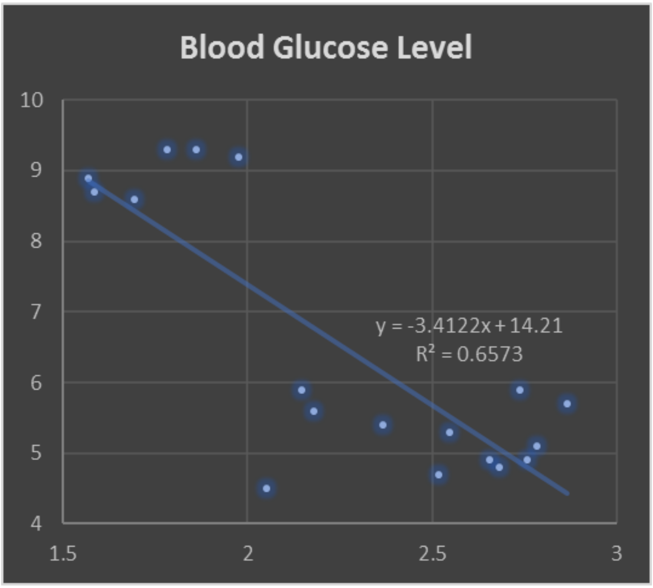


Figure 12: Graph of Blood Glucose Level versus GSR Data

Based on the analysis of data f the linear plot, it is concluded that there is a correlation between the skin response and blood glucose level, but there are some factors that affecting stability reading of the GSR data which make prevent the possibility of predicting the blood glucose reading it based on the GSR value precisely.

The way of GSR functioning is that the subject body will act as the resistor and thus the voltage output will be differing from time to time based on the increasing in calories burnt and glucose concentration in the blood. However, the resistance value can also be affected by another factor as it is tended to be distorted and change when there are a vigorous movement, sweating and some other factors.

## IV. CONCLUSION

We manage to implement a low power wearable embedded system to continuously monitor the glucose level in human blood by using GSR sensor. It is compact with battery power supply and able to connect with the smartphone wirelessly to log the data twelve hours continuously. As for the results, it is clearly demonstrated that GSR is inversely proportionate to the value of the blood glucose level. With further investigation, this can be very useful as an alternative method for a non-invasive approach to reading the blood glucose level. Other than that, the threshold (+-2V) is identified for the end user to take note and thus decided whether to carry out the glucometer test for the more accurate result.

## ACKNOWLEDGMENT

Authors would like to thank Machine Learning & Signal Processing (MLSP) research group under Center for Telecommunication Research and Innovation (CeTRI) of Universiti Teknikal Malaysia Melaka (UTeM) and Faculty of Electronics and Computer Engineering (FKEKK), UTeM for the use of existing facilities to complete this project. Authors would also like to thank Ministry of Science, Technology and Innovation (MOSTI), Malaysia for sponsoring this work under project 01-01-14-SF0133/L00029.

## REFERENCES

[1] World Health Organization, "Diabetes," 2016. [Online]. Available: http://www.who.int/mediacentre/factsheet s/fs312/en/index.html.
[2] N. Akmal, B. Abd, W. Hidayat, Z. B. Manap, and F. Salehuddin, "The Evolution of Non-invasive Blood Glucose Monitoring System for Personal Application," J. Telecommun. Electron. Comput. Eng., vol. 8, no. 1, pp. 59–65, 2016.
[3] C. Tronstad, G. E. Gjein, S. Grimnes, Ø. G. Martinsen, A.-L. Krogstad, and E. Fosse, "Electrical measurement of sweat activity," Physiol. Meas., vol. 29, no. 6, pp. S407–S415, 2008.
[4] DFRobot Bluno, "Bluno Bettle SKU:DFR0339." [Online]. Available: https://www.dfrobot.com/wiki/index.php/Bluno_Beetle_SKU:DFR0339.
[5] Neil Smyth, "Android Studio Development Essentials," 2015.
[6] Crunchbase, "Firebase Crunchbase." [Online]. Available: https://www.crunchbase.com/organization/firebase. [Accessed: 29-Apr-2017].