

# Application Note Customized Glucometer using GreenPAK

# AN-CM-222

#### Abstract

This application note shows how to develop a custom glucometer used a Dialog GreenPAK™ SLG46580V and SLG88104V.

This Application Note comes complete with design files which can be found in the References section

### AN-CM-222



### Customized Glucometer using GreenPAK

### Contents

Ab	stract	1
Со	ntents	2
Fig	jures	2
Та	bles	2
1	Terms and Definitions	3
2	References	3
3	Introduction	4
4	Hardware Schematic	4
5	Glucometer Blood Test Strip	5
6	GreenPAK Design	5
7	Timing Diagrams	7
8	Comparison and Benefits	8
9	Conclusion	8
Re	vision History	9

# **Figures**

Figure 1: Hardware Schematic	4
Figure 2: Glucometer Blood Test Strip	5
Figure 3: GreenPAK Design	
Figure 4: System signals when 300mv < ANALOG IN < 350mv	
Figure 5: System Signals when ANALOG_IN > 400 mv	

## **Tables**

Table 1: Analog Comparator Outputs for Different Glucose Levels 6
---



### **1** Terms and Definitions

CMIC Configurable Mixed-Signal Integrated Circuits

#### 2 References

For related documents and software, please visit:

https://www.dialog-semiconductor.com/configurable-mixed-signal.

Download our free GreenPAK Designer software [1] to open the .gp files [2] and view the proposed circuit design. Use the GreenPAK development tools [3] to freeze the design into your own customized IC in a matter of minutes. Dialog Semiconductor provides a complete library of application notes [4] featuring design examples as well as explanations of features and blocks within the Dialog IC.

- [1] GreenPAK Designer Software, Software Download and User Guide, Dialog Semiconductor
- [2] AN-CM-222 Customized Glucometer using GreenPAK.gp, GreenPAK Design File, Dialog Semiconductor
- [3] GreenPAK Development Tools, GreenPAK Development Tools Webpage, Dialog Semiconductor
- [4] GreenPAK Application Notes, GreenPAK Application Notes Webpage, Dialog Semiconductor
- [5] SLG46580V, Datasheet, Dialog Semiconductor
- [6] SLG88104V, Datasheet, Dialog Semiconductor



### 3 Introduction

Glucometers play an important role in managing a diabetic patient's health issues. Typically, the patient inserts a disposable test strip into the meter, pricks their finger, loads a droplet of blood onto the test strip, waits a couple seconds, and then receives a reading of the current blood glucose level.

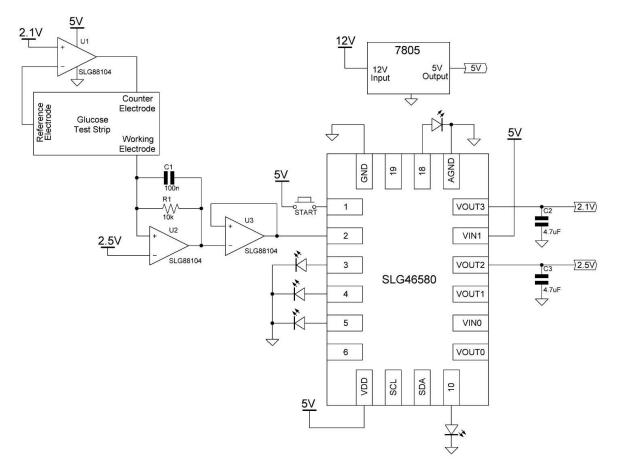
The designs available on the market today are costly, large, and power inefficient. The design proposed in this app note uses the analog voltage signal generated by a blood drop on a customized Glucometer strip to measure glucose levels. The signal is amplified and fed into a Dialog GreenPAK SLG46580V CMIC. The GreenPAK decodes the voltage signal and compares it with preset thresholds to determine the glucose level.

The glucometer blood test strip used in this design is a typical one available on the market. The GreenPAK design can be easily modified to adjust the threshold levels of different glucose ranges. We've also included Reset and Start functions to make the design more reliable.

Different glucometer blood test strips may have different connections, so be sure to check the connections before implementing this design.

### 4 Hardware Schematic

The hardware schematic is shown in Figure 1.



#### Figure 1: Hardware Schematic

The external 7805 voltage regulator is used to generate +5 V from the +12 V DC Adapter.

When a blood droplet is placed on the glucometer strip, a short circuit is created between the reference electrode and the counter electrode. This allows U1 (SLG88104V) to act as a unity gain amplifier. The output voltage is equal to the input voltage applied at the '+' terminal, i.e., 2.1 V.

		_	
Δηι	alicat	ion	Note
	Jiicat		

#### AN-CM-222



This short results in current flow between the counter electrode (now at 2.1 V) and the working electrode. The magnitude of the current flow is proportional to the glucose level of the blood drop.

The op-amp U2 (SLG88104V) acts as transimpedance amplifier. The output voltage of this amplifier can be calculated with the following formula:

Vout = [Current flow between the Counter and Working electrodes] \* R1

The 100 nF capacitor C1 is used to maintain smooth voltage.

Op-amp U3 is another unity gain amplifier which maintains a constant voltage at its output. The purpose of using 2.5 V and 2.1 V in this circuit is to maintain a voltage difference of 400 mV across two of the test strip electrodes. This is necessary for the glucometer to function properly.

The output voltage of op-amp U3 is then fed to the SLG46580V's Pin6, which is configured as an analog input/output.

### 5 Glucometer Blood Test Strip

A typical glucometer strip is shown in Figure 2. The connections of the test strip are:

- 1 Reference electrode
- 2 Counter electrode
- 3 Working electrode
- 4 and 5 Test electrodes. These two electrodes are used to detect that the strip is inserted in the slot reserved for the strip. These two electrodes are not necessary for the functioning of the glucometer.

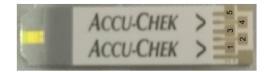


Figure 2: Glucometer Blood Test Strip

The connections may vary for different vendor strips; however, there should always be a reference, counter, and working electrode.

In each test strip, there is an enzyme called glucose oxidase. This enzyme reacts with the glucose in the blood sample and creates gluconic acid.

The gluconic acid then reacts with another chemical in the testing strip, called ferricyanide. The ferricyanide and the gluconic acid combine to create ferrocyanide.

Once the ferrocyanide has been created, current moves through the blood sample on the strip. The level of current allows the GreenPAK to read the level of ferrocyanide and determine how much glucose is in the sample of blood.

The output voltage from the circuit used above will range between 0 and 350 mV for typical glucose levels.

#### 6 GreenPAK Design

The four analog comparators (ACMPs) are used to determine the voltage of the ANALOG\_IN signal received at Pin2. This design has 5 possible glucose levels, and each level corresponds to a particular voltage range. The table below gives the analog voltage ranges for each of the glucose levels.

_			
Λn	nlice	ation	0
AP		aliui	.С

#### AN-CM-222



#### **Customized Glucometer using GreenPAK**

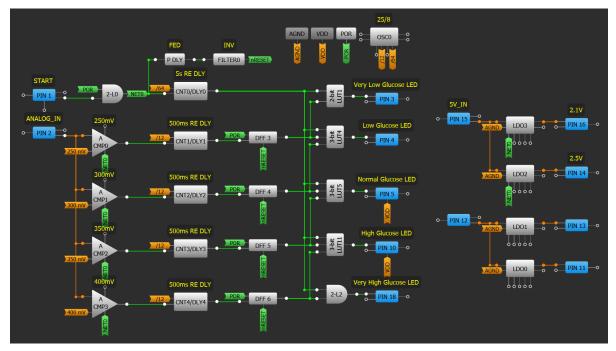


Figure 3: GreenPAK Design

Sr. No	Analog Voltage Range (mV)	Glucose Level	Glucose Level in mmol / L	ACMP0 Output	ACMP1 Output	ACMP2 Output	ACMP3 Output
1.	0 ≤ V < 250	Very Low	0 to 4	Low	Low	Low	Low
2.	250 ≤ V < 300	Low	4 to 5	High	Low	Low	Low
3.	300 ≤ V < 350	Normal	5 to 6	High	High	Low	Low
4.	350 ≤ V < 400	High	6 to 7.5	High	High	High	Low
5.	V ≥ 400	Very High	above 7.5	High	High	High	High

Table 1: Analog	Comparator	Outputs for	Different	Glucose Levels
	oomparator	outputoioi		

To prevent false readings, we included several 500 ms delay blocks between the ACMPs and the rest of the circuit. These delays will help filter out any spurious signals. The sensitivity of the glucometer can be varied by varying the delay time of these delay blocks.

Since the voltage received at ANALOG\_IN (Pin2) is the result of current flowing between the counter electrode and the working electrode on the test strip, the current will only last for a short period of time and may disappear quickly. In order to hold the voltages for a longer period, we used capacitor C1. However, even with the capacitor, the voltage will dissipate, causing all of the ACMPs to be LOW. To save the ANALOG\_IN voltage value, we used 4 DFFs to store the analog voltage range information at the output of the 4 delay blocks.

To reduce power consumption, each ACMP is only powered on once the ANALOG\_IN voltage is high enough for the next ACMP to be required. For instance, if the ANALOG\_IN voltage is 325 mV and the START input goes HIGH, ACMP0 will be turned on immediately so that it can determine whether ANALOG\_IN is greater than 250 mV.

Since ANALOG\_IN > 250 mV, after 500 ms CNT1/DLY1 will go HIGH, which will clock DFF3 and power on ACMP1. ACMP1 will now check whether ANALOG\_IN is greater than 300 mV. Again, since it is greater than 300 mV, in 500 ms the output of CNT2/DLY2 goes HIGH, which clocks DFF4 and powers on ACMP2.

At this point ANALOG\_IN < 350 mV, so ACMP2 will stay LOW, meaning that DFF5 and DFF6 will both stay LOW.

Application Note	Revision 1.0	26-Feb-2018



Once 5 seconds has elapsed from the time that the START signal went HIGH, CNT0/DLY0 will go HIGH. This signal, as well as the DFF outputs, are connected to Look-Up Tables (LUTs), either 2-bit or 3-bit. These LUTs resolve which LED should be lit to indicate the level of glucose.

When the START signal goes LOW, a short reset pulse is triggered using the PDLY as a falling edge detector along with inverter FILTER0. This short, active-low pulse will reset the four DFFs. This will consequently power off all of the ACMPs, and ready the system to take another reading.

# 7 Timing Diagrams

Time (Seconds)	0 0.5	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7	7.5	8	8.5	9	9.5	10
START (ACMP0 PWR_ON)																				
Delayed ACMP0 output (ACMP1 PWR_ON)																				
Delayed ACMP1 output (ACMP2 PWR_ON)																				
Delayed ACMP2 output (ACMP3 PWR_ON)																				
Delayed ACMP3 OUTPU	г																			_
5s DLY OUTPUT																				
Pin3 (Very Low Glucose LED)																				
Pin4 (Low Glucose LED)	. <u> </u>												1							
Pin5 (Normal Glucose LED)																				
Pin10 (High Glucose LED)																				
Pin18 (Very High Glucose LED)																				
nRESET																		╌		-
											(This	section	ر۔۔۔ n not to	scale)						
-	igure	A. 6	Svot	~ m	oiar		wh	~~ ·	200-				~~	INI	. 25	0				
ſ	iguic	4. 、	5y510		siyi	1013	wn	en .	3001	nv ·	< AN	IAL	UG_		<	Um	V			
Time (Seconds)	0.5	<b>4. .</b>	1.5	2	2.5	3	3.5	4 en	3 <b>UU</b> I 4.5	nv • 5	5.5	6 6	6.5	_IIN 7	< 33 7.5	8	8.5	9	9.5	10
	_		-		_													9	9.5	10
Time (Seconds) START	_		-		_													9 	9.5	10
Time (Seconds) START (ACMP0 PWR_ON) Delayed ACMP0 output	_		-		_													9 	9.5	10
Time (Seconds) START (ACMP0 PWR_ON) Delayed ACMP0 output (ACMP1 PWR_ON) Delayed ACMP1 output	_		-		_													9  	9.5	10 
Time (Seconds) START (ACMP0 PWR_ON) Delayed ACMP0 output (ACMP1 PWR_ON) Delayed ACMP1 output (ACMP2 PWR_ON) Delayed ACMP2 output	0.5		-		_													9  	9.5	10 
Time (Seconds) START (ACMP0 PWR_ON) Delayed ACMP0 output (ACMP1 PWR_ON) Delayed ACMP1 output (ACMP2 PWR_ON) Delayed ACMP2 output (ACMP3 PWR_ON)	0.5		-		_													9   	9.5	10 
Time (Seconds) START (ACMP0 PWR_ON) Delayed ACMP0 output (ACMP1 PWR_ON) Delayed ACMP1 output (ACMP2 PWR_ON) Delayed ACMP2 output (ACMP3 PWR_ON) Delayed ACMP3 OUTPUT	0.5		-		_													。 	9.5	10 
Time (Seconds) START (ACMP0 PWR_ON) Delayed ACMP0 output (ACMP1 PWR_ON) Delayed ACMP1 output (ACMP2 PWR_ON) Delayed ACMP2 output (ACMP3 PWR_ON) Delayed ACMP3 OUTPUT 5s DLY OUTPUT Pin3	0.5		-		_													。 	9.5	
Time (Seconds) START (ACMP0 PWR_ON) Delayed ACMP0 output (ACMP1 PWR_ON) Delayed ACMP1 output (ACMP2 PWR_ON) Delayed ACMP2 output (ACMP3 PWR_ON) Delayed ACMP3 OUTPUT 5s DLY OUTPUT Pin3 (Very Low Glucose LED) Pin4	0.5		-		_													。    	9.5	10 
Time (Seconds) START (ACMP0 PWR_ON) Delayed ACMP0 output (ACMP1 PWR_ON) Delayed ACMP1 output (ACMP2 PWR_ON) Delayed ACMP2 output (ACMP3 PWR_ON) Delayed ACMP3 OUTPUT Pin3 (Very Low Glucose LED) Pin5	0.5		-		_													°  	9.5	10 
Time (Seconds) START (ACMP0 PWR_ON) Delayed ACMP0 output (ACMP1 PWR_ON) Delayed ACMP1 output (ACMP2 PWR_ON) Delayed ACMP2 output (ACMP3 PWR_ON) Delayed ACMP3 OUTPUT Ss DLY OUTPUT Pin3 (Very Low Glucose LED) Pin4 (Low Glucose LED) Pin5 (Normal Glucose LED) Pin10	0.5		-		_													°	9.5	
Time (Seconds) START (ACMP0 PWR_ON) Delayed ACMP0 output (ACMP1 PWR_ON) Delayed ACMP1 output (ACMP2 PWR_ON) Delayed ACMP2 output (ACMP3 PWR_ON) Delayed ACMP3 OUTPUT 5s DLY OUTPUT Pin3 (Very Low Glucose LED) Pin4 (Low Glucose LED) Pin5 (Normal Glucose LED) Pin10 (High Glucose LED) Pin18	0.5		-		_														9.5	

#### Figure 5: System Signals when ANALOG\_IN > 400 mv

**Application Note** 



### 8 Comparison and Benefits

Compared to a typical glucometer, this GreenPAK-based Glucometer is smaller, less expensive, and more energy efficient. The design could easily be modified for patients with Type-1 or Type-2 diabetes.

### 9 Conclusion

In this application note, Dialog GreenPAK SLG46580V and SLG88104V was used to develop a custom glucometer. The concepts used in the app note could be modified to fit other medical applications. Thanks to their small size and low energy consumption, Dialog's GreenPAK products make it possible for this design to be portable and energy efficient.



# **Revision History**

Revision	Date	Description
1.0	26-Feb-2018	Initial version.

**Application Note** 



#### **Status Definitions**

Status	Definition
DRAFT	The content of this document is under review and subject to formal approval, which may result in modifications or additions.
APPROVED or unmarked	The content of this document has been approved for publication.

#### **Disclaimer**

Information in this document is believed to be accurate and reliable. However, Dialog Semiconductor does not give any representations or warranties, expressed or implied, as to the accuracy or completeness of such information. Dialog Semiconductor furthermore takes no responsibility whatsoever for the content in this document if provided by any information source outside of Dialog Semiconductor.

Dialog Semiconductor reserves the right to change without notice the information published in this document, including without limitation the specification and the design of the related semiconductor products, software and applications.

Applications, software, and semiconductor products described in this document are for illustrative purposes only. Dialog Semiconductor makes no representation or warranty that such applications, software and semiconductor products will be suitable for the specified use without further testing or modification. Unless otherwise agreed in writing, such testing or modification is the sole responsibility of the customer and Dialog Semiconductor excludes all liability in this respect.

Customer notes that nothing in this document may be construed as a license for customer to use the Dialog Semiconductor products, software and applications referred to in this document. Such license must be separately sought by customer with Dialog Semiconductor.

All use of Dialog Semiconductor products, software and applications referred to in this document are subject to Dialog Semiconductor's Standard Terms and Conditions of Sale, available on the company website (www.dialog-semiconductor.com) unless otherwise stated.

Dialog and the Dialog logo are trademarks of Dialog Semiconductor plc or its subsidiaries. All other product or service names are the property of their respective owners.

© 2018 Dialog Semiconductor. All rights reserved.

## **Contacting Dialog Semiconductor**

United Kingdom (Headquarters) Dialog Semiconductor (UK) LTD Phone: +44 1793 757700

#### Germany

Dialog Semiconductor GmbH Phone: +49 7021 805-0

#### The Netherlands

Dialog Semiconductor B.V. Phone: +31 73 640 8822 Email:

enquiry@diasemi.com

# Application Note

#### North America

Dialog Semiconductor Inc. Phone: +1 408 845 8500

#### Japan Dialog Semiconductor K. K.

Phone: +81 3 5769 5100

Taiwan

Dialog Semiconductor Taiwan Phone: +886 281 786 222 Web site:

www.dialog-semiconductor.com

Hong Kong

*Dialog Semiconductor Hong Kong* Phone: +852 2607 4271

Korea Dialog Semiconductor Korea Phone: +82 2 3469 8200

#### China (Shenzhen)

Dialog Semiconductor China Phone: +86 755 2981 3669

China (Shanghai) Dialog Semiconductor China Phone: +86 21 5424 9058

Revision 1.0

#### CFR0014

10 of 10

26-Feb-2018