

AN-1134 Drawing Characters on an Android App and Displaying it on LED Matrix

This Application Note describes the circuit used to go from drawing a character on an Android App, sending it to an Arduino UNO via Bluetooth, then to a GreenPAK™ via I2C which fits data to display the character on a LED matrix. Using the GreenPAK5 frees up the necessary Arduino GPIO's so that Bluetooth can be used, along with leaving GPIO's available for other purposes. Additional benefits of GreenPAK include the I2C protocol needing just 2 wires to control, for up to 16 GreenPAK5 from one I2C master. So if we want to connect more than one LED matrix to the Arduino UNO, using multiple GreenPAK's is a much more economical design. And once the GreenPAK is loaded with a character, it can work independently even if the I2C connection is disconnected.

Project Design Approach

This project uses an android app., and the app uses a virtual LED matrix. Therefore, you can update the character that is seen on the LED matrix from the mobile device directly.

This project consists of three stages:

1. Build the Android application
2. GreenPAK design
3. Arduino code

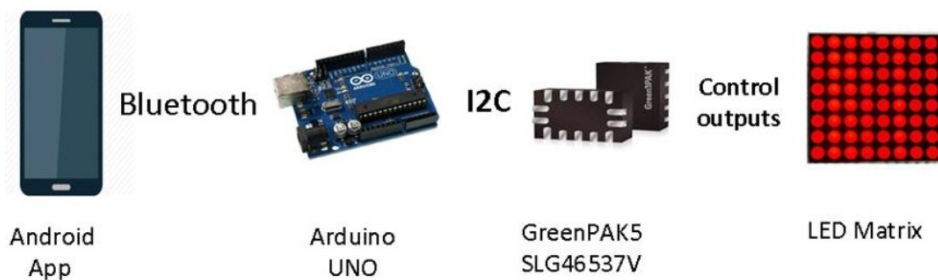


Figure 1. Components used in this App Note

Working principle of the LED matrix

LED dot matrices are very popular as they are very visible in a variety of ambient conditions.

In a dot matrix display, multiple LEDs are wired together in rows and columns in order to minimize the number of pins required. For example, an 8×8 matrix of LEDs (Figure 2) has the cathodes together in rows (R1 through R8) and anodes in columns (C1 through C8). Each LED is addressed by its row and column number. In this example we are using what is referred to as a Common Row Cathodes LED Matrix.

To illuminate a LED pixel in the matrix, a high signal is applied on the anode (column) and low signal is sent to the cathode (row). When we want to show characters or symbols, we typically need to illuminate numerous pixels. In this case, we divide the picture into sections, and we illuminate every row in a fast loop separately.

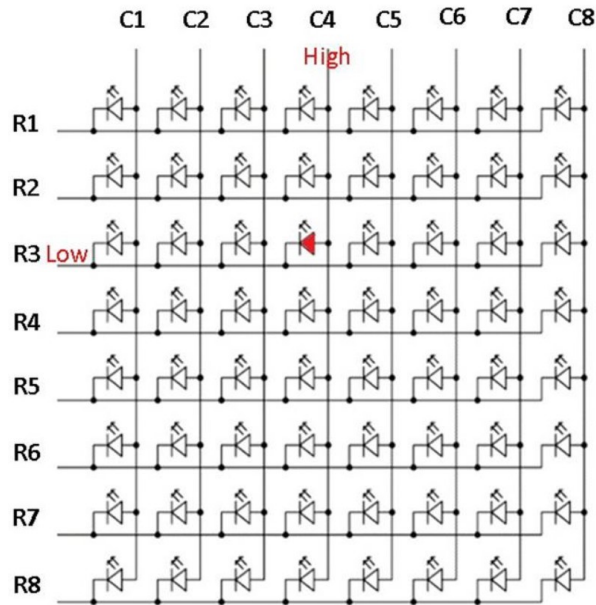


Figure 2. LED matrix diagram

The human eye can detect LEDs blinking at low frequency, but at more than 20Hz, the full character will appear and with less flicker. In this design, we will control an 8x7 LED matrix, as the last column C8 will be omitted because of a limitation of IO pins.

Android Application

For this first stage, an application for android devices is built to send data to the Bluetooth module. The app will have the graphical interface to the user.

The app interface has 56 buttons. Each button represents a pixel in the LED matrix, hence, each one will be represented by a binary variable with two states (on=1, off=0).

Every LEDs' row is represented by one byte (bit for pixel). To find the byte's value, we multiply every button state by the significant bit and then we take the sum of products.

p1..p64 are binary variables hold buttons states (**on =1, off=0**).

$$B1 = (P1 \times 1) + (P2 \times 2) + (P3 \times 4) + (P4 \times 8) + (P5 \times 16) + (P6 \times 32) + (P7 \times 64) + (0)$$

$$B8 = (P57 \times 1) + (P58 \times 2) + (P59 \times 4) + (P60 \times 8) + (P61 \times 16) + (P62 \times 32) + (P63 \times 64) + (0)$$

After this calculation, the character will be represented by 8 bytes (**B1..B8**) which will be sent to the Bluetooth module.

| Bit Significant | x 1 | x 2 | x 4 | x 8 | x 16 | x 32 | x 64 | x0 | |
|-----------------|-----|-----|-----|-----|------|------|------|----|----------|
| Column | C1 | C2 | C3 | C4 | C5 | C6 | C7 | C8 | Row BYTE |
| R1 | P 1 | P2 | P3 | P4 | P5 | P6 | P7 | 0 | B1 |
| R2 | P9 | P10 | P11 | P12 | P13 | P14 | P15 | 0 | B2 |
| R3 | P17 | P18 | P19 | P20 | P21 | P22 | P23 | 0 | B3 |
| R4 | P25 | P26 | P27 | P28 | P29 | P30 | P31 | 0 | B4 |
| R5 | P33 | P34 | P35 | P36 | P37 | P38 | P39 | 0 | B5 |
| R6 | P41 | P42 | P43 | P44 | P45 | P46 | P47 | 0 | B6 |
| R7 | P49 | P50 | P51 | P52 | P53 | P54 | P55 | 0 | B7 |
| R8 | P57 | P58 | P59 | P60 | P61 | P62 | P63 | 0 | B8 |

Table 1. Control bits for LED matrix

MIT APP Inventor

The app can be made using the MIT App Inventor with ease and no prior programming experience is required. The app Inventor lets you develop applications for Android phones using a web browser with programming blocks.

To create the Android Application, a new project has to be started and the visible components need to be removed from the designer screen. Then 58 buttons need to be created; 56 buttons will be for the LED matrix, 1 will be for the list pickers for the Bluetooth devices (connect), and the last button will be used to send data via Bluetooth (print). We also need a Bluetooth client. Figure 3 below is a screen capture of our Android Application's user interface.

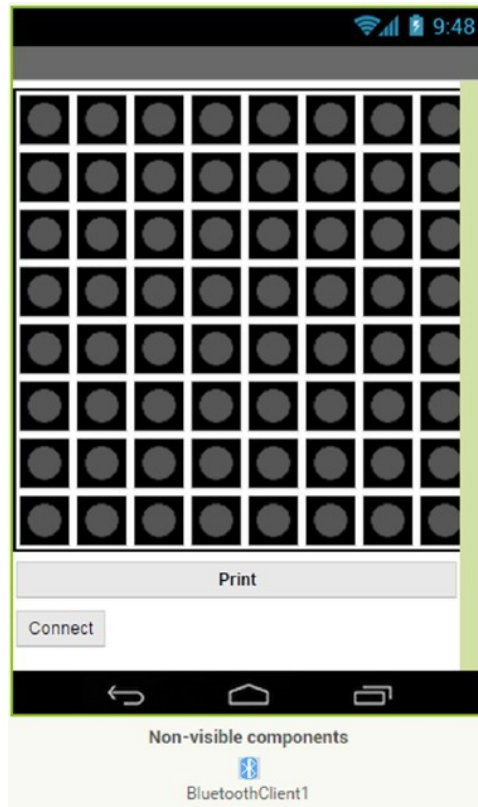


Figure 3. Android App GUI

To start programming, the "Block" button needs to be clicked. By dragging and dropping, we can add components from the bar on the left side. As in Fig 4, the global variables will be added and on-click functions for each button have to be built which will be used to change colors and/or to save the button state (on , off).

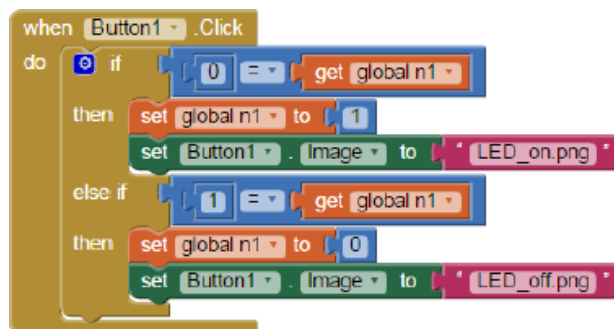


Figure 4. Block diagram for first matrix pixel

For different buttons, the process can be repeated by changing the button number and the global variable each time. Once done, the mathematical equation needs to be built which will gather every row's bits in one byte (B1..B8 equations). The 56 button states will be formed in 8 bytes variables. (Fig. 5 illustration).



Figure 5. Gathering bits in rows bytes

Finally, the app will send the 8 bytes using Bluetooth as a list of bytes when the print button is clicked (Fig. 6).

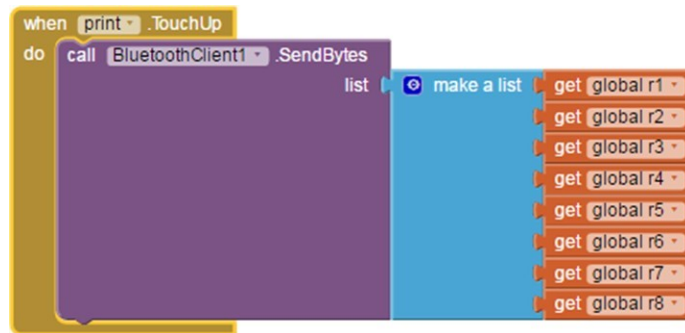


Figure 6. Send row bytes via Bluetooth

GreenPAK design

The Android application sends data to the Arduino, and then from Arduino to GreenPAK via I2C connection. Those details are explained in the "Arduino code" section later. The I2C interface in SLG46537V is very powerful because it can read and write all its configuration bits (including output states and ASM RAM). The I2C write command begins with a start bit, followed by a control byte, word address byte, data byte and stop bit (illustrated in Fig 7).

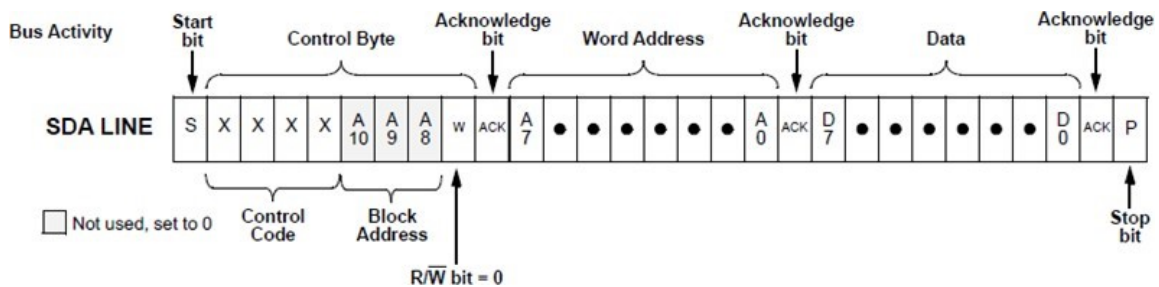


Figure 7. I2C Writing Frame

In GreenPAK we start designing the I2C block. This block is enabled from the properties bar and then the control code is chosen. Then two wires will be connected with pins 8, 9(SCL, SDA) and from the control code list, the device address is chosen (a number from 0 to 15). In our project 0 (0b0000) is selected. This is shown in Fig 8.

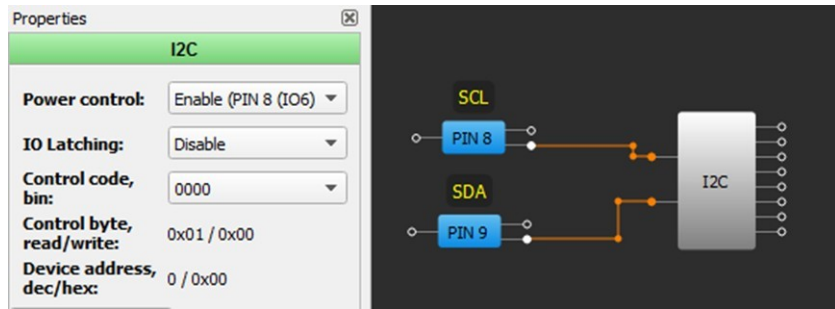


Figure 8. I2C block connection

A controller that will show bytes in rows needs to be made. For that, a State Machine block (ASM) has to be used. The ASM block is an 8-state asynchronous state machine. There are 24 state transition inputs, 1 nRESET input and 8 output lines. The ASM block is defined using state transitions and state outputs. Every state will represent one row and it will show the byte that is received from Arduino.

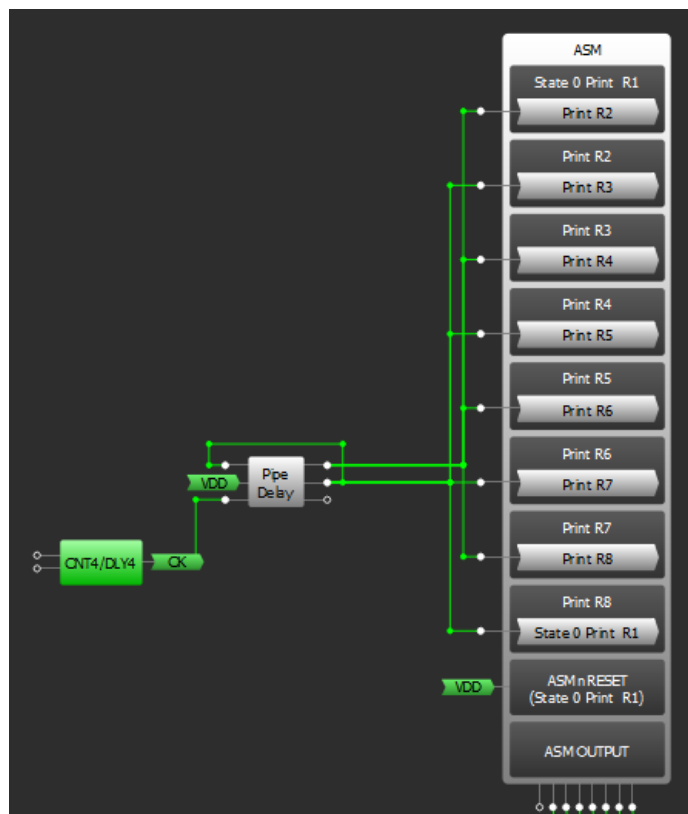


Figure 9. Connect ASM block with pulse generator

The movement from the current state to the next one happens by applying a high signal on the next state enable's pin and a low signal on the current state enable's pin.

Take State 0 for example: its box contains a state 1 arrow as the next state. This means that in order to transition from State 0 to 1, the input of the State 1 arrow needs to be high when the ASM is in state 0.

A counter with pipe delay will be responsible to generate the pulse. CNT4 is used to generate a 0.32ms timer that is used as the one-shot pulse width for all the states. Since the ASM's inputs are level triggered and not edge triggered, the CNT4's output can't simply be used as the trigger for all state transitions (because it would cause almost instantaneous transitions from a state to another instead of waiting for 0.32ms between transitions).

To address this, the Pipe Delay macro-cell is used to generate 2 complementary outputs with 50% duty cycle. While one signal is used to transition from even to odd numbered states, the other is

used to transition from odd to even numbered states.

This design can be approached from the ASM properties bar or from the ASM editor as shown in Figure 9. The ASM Editor is provided with a graphical buttons panel to set the ASM output for each state (connection matrix output RAM). So the initial character (which is to be displayed on the LED matrix) can be drawn before updating from mobile app.

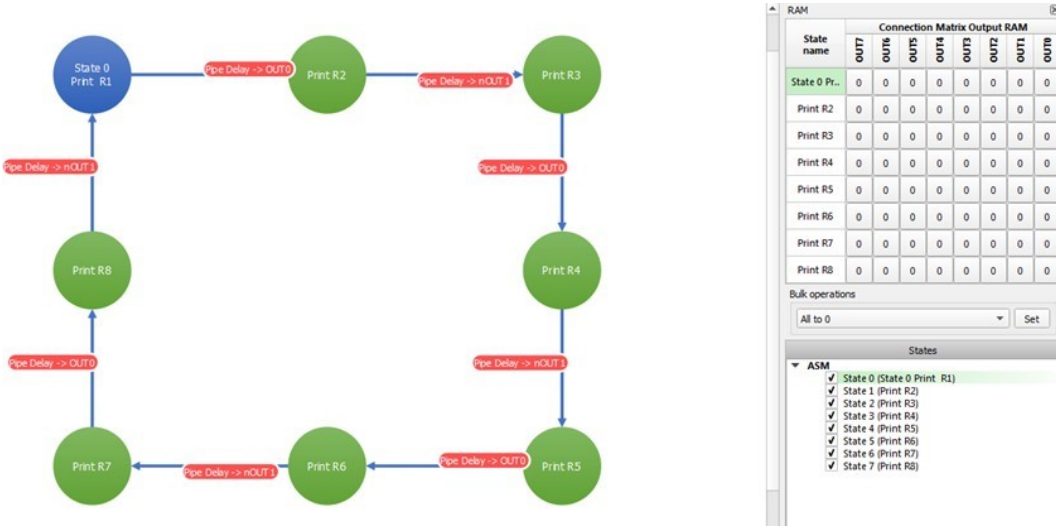


Figure 10. ASM Editor Diagram

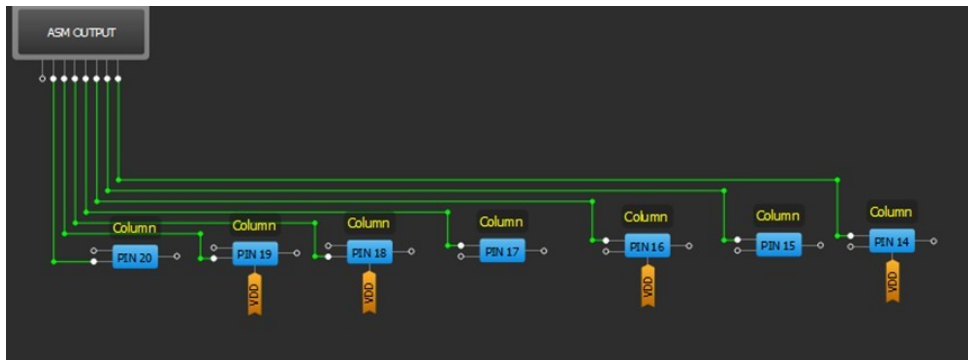


Figure 11. Connect ASM outputs with columns pins

In every state, the ASM output will be the row byte which we want to show, so we connect the ASM outputs directly to the GreenPAK output pins which are in turn connected to the LED matrix columns, (pins 14 to 20).

With every state, one row that is related to the state has to be activated and because the cathodes are wired together in rows, the active signal for rows is low; hence, a low signal is applied on the related row. A series of 8 DFF will give a low signal on one output (with every CLK) while giving a high signal for the other outputs.

This low signal will move from one row to the next with every rising edge's CLK. To do that, the output of every DFF is connected with the next DFF's Dpin. (The last one feeds back to the first DFF to complete the loop). The initial polarity of the first DFF is low while it is high for the other DFFs.

B.O.M and Tools

The components used in this project are:

- SLG46537V GreenPAK5 device <https://www.dialog-semiconductor.com/products/slg46537>
- HC-06 Bluetooth module
- Arduino UNO board <https://www.sparkfun.com/products/11021>
- 8x8 Common Row Cathodes LED Matrix <https://www.adafruit.com/products/455> - 200 ohm resistors

- GreenPAK designer Go Configure™ Software Hub | Renesas
- Arduino IDE <https://www.arduino.cc/en/Main/Software>

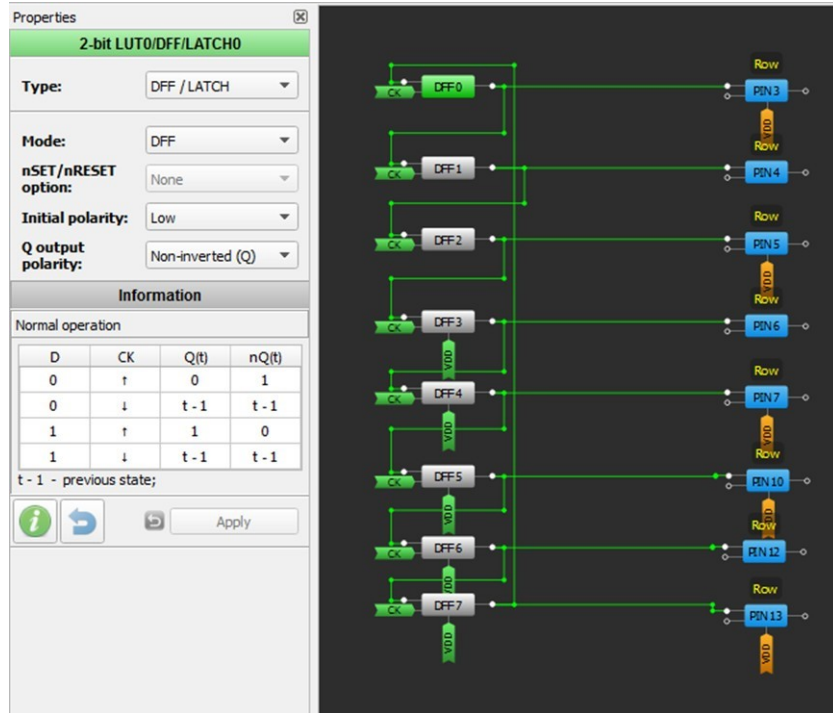


Figure 12. Activation of one row with every state

Arduino Code

In this stage, the Arduino, which is connected with the Bluetooth module, will receive the 8 bytes using the UART interface. It will perform data fitting and will send them to the GreenPAK5 using I2C. The HC06 module that has been used for Bluetooth communication uses the UART for communication protocol with a 9600 baud rate. That number will be used in the code.

Arduino UNO has a serial interface connected with pins 0,1 (RX,TX) to make the UART connection with other components. So the Bluetooth module TX will be connected with the Arduino RX (pin 0). Bluetooth module TX > Arduino RX (pin 0).

After receiving data bytes, Arduino has to be used to send these bytes (using i2C protocol) to GreenPAK. To make this easy, Silego's Arduino Library has been used.

Silego's Arduino Library is a custom library. By using it, data can easily be read from or written to a GreenPAK device from the Arduino using I2C. There are two functions available in the Silego library: writeI2C and readI2C. The syntax to call one of these functions in an Arduino sketch is `silego.function(parameters);` In our project, the writeI2C function will be used, which has this form: `void writeI2C(byte byte_address, byte data);`

| Variable | Function |
|--------------|--|
| byte_address | The GreenPAK register address which we want to write |
| byte data | Data which has to be written on the address. |

Table 2. Arduino writing function variables

The byte address is found in the SLG datasheet. In our project, the byte addresses that we will use

are the addresses of the RAM 8 outputs for ASM-states, as shown in table 3. However, because the Arduino is used as I2C master, a Silego library for Arduino will have to be used in order to get static variable names instead of HEX numbers in Arduino functions as shown in the 3rd column of table 3.

| Address byte | Signal Function | Arduino static variables |
|--------------|------------------------------|--------------------------|
| D0 | RAM 8 outputs for ASM-state0 | ASM_STATE_0 |
| D1 | RAM 8 outputs for ASM-state1 | ASM_STATE_1 |
| D2 | RAM 8 outputs for ASM-state2 | ASM_STATE_2 |
| D3 | RAM 8 outputs for ASM-state3 | ASM_STATE_3 |
| D4 | RAM 8 outputs for ASM-state4 | ASM_STATE_4 |
| D5 | RAM 8 outputs for ASM-state5 | ASM_STATE_5 |
| D6 | RAM 8 outputs for ASM-state6 | ASM_STATE_6 |
| D7 | RAM 8 outputs for ASM-state7 | ASM_STATE_7 |

Table 3. ASM outputs state addresses

The "SilegoLibrary.zip" folder needs to be downloaded. The folder needs to be unzipped in the Arduino libraries directory before programming. The folder name has to have no spaces. For detailed information you can see [AN-1107 How to Use Silego's Arduino Library with GreenPAK](#).

This library is compatible with SLG46531V, SLG46532V, SLG46533V. However, we can use it with SLG46537V because SLG46531V and SLG46537V have the same I2C addresses.

I2C Arduino UNO pins: SCL--->A5 , SDA--->A4.

The final code:

```
#include <Wire.h>
#include "Silego.h" // Include Silego header file
#include "macros/SLG46531.h" // Include macros for SLG46531
byte rows_byte[8]; //matrix to hold rows bytes
int i=0 ; //counter
boolean s=0; //state flag

// Create an instance of Silego class called
// "silego" with device address 0x00
Silego silego(0x00);
void setup() {
  Serial.begin(9600); //Bluetooth module's baud rate
}
void loop() {
  while(Serial.available()>0) //receiving bytes coming from
  { //Bluetooth
    rows_byte[i]=Serial.read();
    delay(5);
    i++;
    s=1; //set flag
  }
  if(s==1) // send bytes to GreenPAK using I2C
  {
    silego.writeI2C(ASM_STATE_0, rows_byte[0]);
    silego.writeI2C(ASM_STATE_1, rows_byte[1]);
    silego.writeI2C(ASM_STATE_2, rows_byte[2]);
    silego.writeI2C(ASM_STATE_3, rows_byte[3]);
    silego.writeI2C(ASM_STATE_4, rows_byte[4]);
    silego.writeI2C(ASM_STATE_5, rows_byte[5]);
    silego.writeI2C(ASM_STATE_6, rows_byte[6]);
    silego.writeI2C(ASM_STATE_7, rows_byte[7]);
    s=0; // Reset flag
    i=0; // Rest counter
  }
}
```


Circuit Schematic

| GreenPAK pin | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
|--------------|-----|----|----|----|----|----|----|----|----|----|
| Function | GND | R7 | R8 | C1 | C2 | C3 | C4 | C5 | C6 | C7 |

| GreenPAK pin | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|--------------|-----|---|----|----|----|----|----|----|----|----|
| Function | VDD | - | R1 | R2 | R3 | R4 | R5 | R6 | R7 | R8 |

Table 4. GreenPAK Output Pins Connection

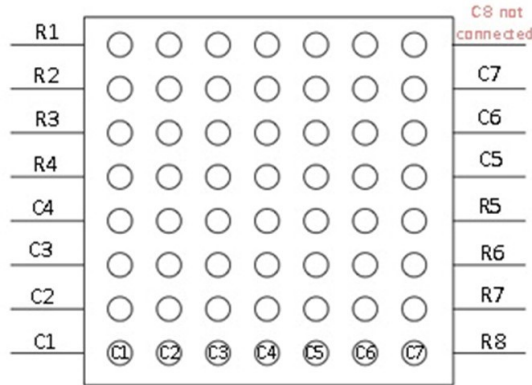


Figure 13. LED Matrix Pins Diagram

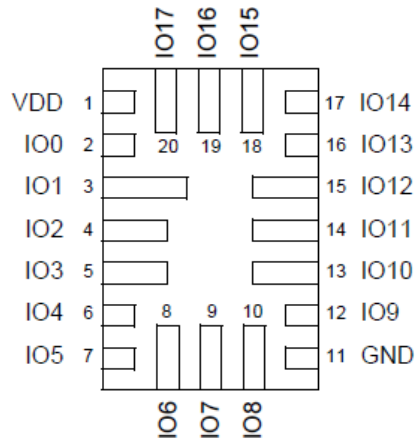


Figure 14. SLG46537V Pinout

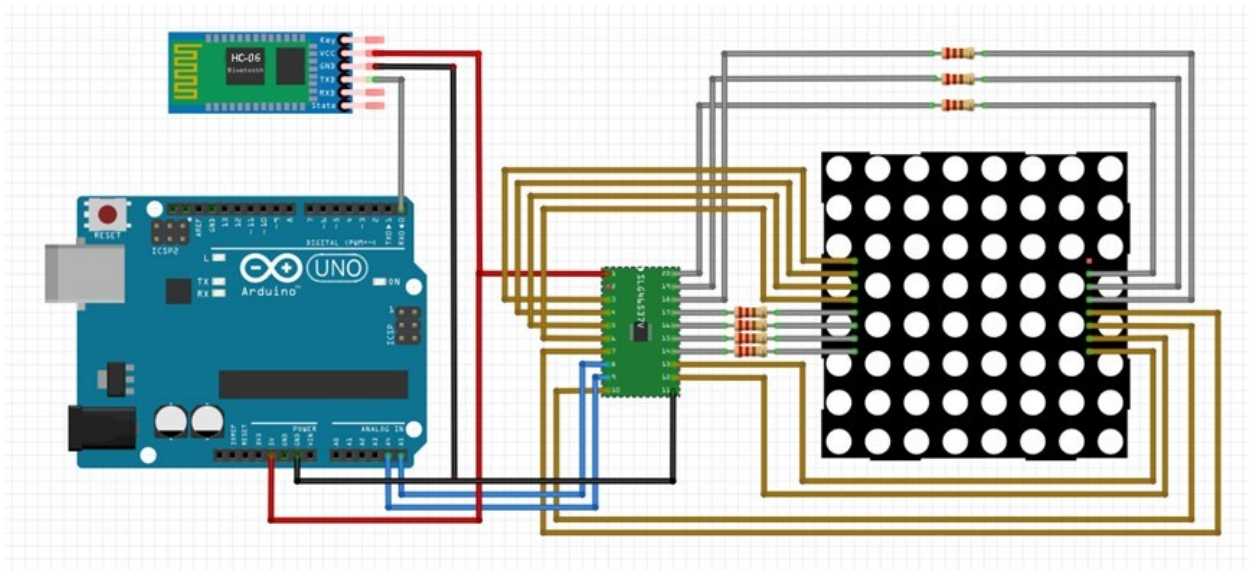


Figure 15. Top level Circuit Schematic

Conclusion

In this Application Note, a LED matrix driver has been created that can be controlled from ucontroller via the I2C protocol. An android app has also been built with a virtual LED matrix to draw characters and to display them on the LED matrix. The GreenPAK Programmable Mixed- signal ASIC has a variety of digital and analog components that facilitate the creation of moderately complex designs. It also has the I2C interface which allows control of GreenPAK registers from any I2C master.

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