

## Introduction

Readers of this magazine have probably come to realize that I am enamored with micro controller projects that blink and flash. Examples published in this magazine include:

1. The Infinity Portal, August 2011
2. The Desktop Contemplator, Dec 2012
3. Smart Necklace, July 2013
4. A Unique LED Clock, March 2014.

The availability of faster and faster micro controllers and individually addressable RGB LEDs is a dream come true for someone like me. So it probably comes as no surprise that when I saw a panel of 32x32 RGB LEDs (1024 LEDs total) at a reasonable price I jumped at the chance to build something with it. This is the same type of panel described in the article, “Giving Life to the Adafruit 32x32 RGB Matrix Panel” by Theron Wierenga in the July 2014 issue of Nuts and Volts.

The project I choose to build I have dubbed “The Light Appliance” because it can be made to do so many fun, interesting and creative things. In a nutshell, the Light Appliance is a Infrared (IR) remote controllable 32x32 RGB LED display that with the hardware and software I will describe:

1. Can run approximately 30 highly colorful graphics routines including plasmas and fractals.
2. Can function as an Open/Closed sign for a business
3. Can function as an analog or digital clock with battery backup.
4. Can function as a decorative mood light
5. Does realtime decoding and display of animated GIF images in 32x32 format.
6. Has General, Christmas, Valentine's, Halloween and 4<sup>th</sup> of July animation modes for your holiday parties.
7. Has time, date and temperature display modes
8. Can function as a canvas for painting with the remote control
9. Can play numerous classic computer games such as Snake, Pac-man, Ending and Breakout.

If you have a fascination with projects like this you can build a Light Appliance of your own. If you have modest electronic skills, can solder and read a schematic you should be good to go.

A somewhat dated video of the Light Appliance in operation is available at:  
<https://www.youtube.com/watch?v=VrOEJqX1-mE>. Many new functions have been added to the Light Appliance since this video was made but the video will give you an idea of how things work.

## Hardware

The brains of the Light Appliance is a Teensy 3.1 micro controller. This controller is much more powerful than your typical Arduino at only about ¼ of the size. Table One details the relevant specifications.

Table One  
Teensy 3.1 Specs

<b>Feature</b>	<b>Spec</b>
CPU – ARM Cortex-M4	Clocked at up to 96 MHz
Flash (program) Memory	256 KBytes
RAM	64 KBytes
EEPROM	2 KBytes
DMA channels	16
Digital I/O	34, 3.3V and 5V tolerant pins
ADC analog to digital converters	2 with 16 bit resolution
DAC digital to analog converters	1 with 12 bit resolution
Timer/Counters	12 total
USB ports	1
Serial ports	3
SPI ports	1
I2C ports	2
CAN bus	1
I2S audio port	1

A Teensy 3.1 controller is shown in Photo One.

Paul Stoffregen of pjrc.com designed and manufactures the Teensy 3.1. Through hard work he has made the Teensy usable in the Arduino Integrated Development Environment (IDE) and has ported many of the most popular Arduino libraries to the Teensy as well. This means you can develop code in the Arduino IDE and download it via USB to the Teensy just as you would if you were using an Arduino. He calls his adaptation of the Teensy into the Arduino environment, Teensyduino. More on the Teensyduino software shortly. Cheers to Paul for a job well done. After using the Teensy 3.1 in a couple of projects I am really impressed with its quality and performance and don't think I'll use a stock Arduino again.

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Note, the Teensy 3.1 must be modified when used in the Light Appliance project. On the bottom of the PCB, there is a trace between two pads that must cut which prohibits powering the Light Appliance display from the USB port. These pads can be seen about half way down this page <https://www.pjrc.com/teensy/teensy31.html> in the Pinouts section. Check out the upper right portion of the rear view of the Teensy 3.1 labeled VUSB. An X-ACTO knife works great for making this cut.

The 32x32 RGB LED matrix we will be using is shown in Photos Two and Three. I won't go into the specifics of the electrical interface required for driving the matrix as all of that is taken care of for you if you use the circuitry shown on the schematic in Figure One. A parts list for the Light Appliance is shown in Figure Two.

The Light Appliance was designed with flexibility in mind. It is possible to build a base system without a Real Time Clock (RTC), without an SD memory card and without the temperature sensor if you so desire. Doing so however severely limits the functionality of the Light Appliance. If you want to include the RTC, you must solder a 32.768 Khz crystal onto the bottom of the Teensy 3.1 controller (see [https://www.pjrc.com/teensy/td\\_libs\\_Time.html#teensy3](https://www.pjrc.com/teensy/td_libs_Time.html#teensy3)). If you want to battery backup your RTC you need to incorporate the optional 3V battery with the connections shown on the schematic. If you want to include the temperature sensor, you must add a DS18B20 sensor and 4.7 K resistor and connect as shown. NOTE: the Light Appliance sketch will need modification if one or more of the optional hardware items are left off. We will show how this is done in a bit.

I have built two Light Appliance units. The first I wired up point to point on a breadboard using the circuitry shown on the schematic. Unfortunately it was kind of a mess and eventually something shorted out and caused my Teensy to emit the magic smoke that we all try and avoid. Luckily there is an alternative which saves some of the breadboarding effort. Louis Beaudoin of pixelmatix.com has made a SmartMatrix Shield Kit for Teensy 3 which makes for a much neater and robust build. I used his shield for my second Light Appliance build. Photo Four shows the assembled shield with the Teensy installed. An expansion connector on the side of the shield makes available most of the Teensy 3.1 pins that are not used in driving the matrix. All of the optional hardware components that I have designed into the Light Appliance still need to be built on a breadboard of some type and attached to the expansion connector on the shield. NOTE: the connection for the RTC backup battery is not made available on the expansion connector so it has to be solder directly to the Teensy PCB. Don't get me wrong, building your Light Appliance on a breadboard without the shield is definitely doable if you take your time and double check your work.

My Light Appliance is powered by a 5 volt 2 amp DC power supply that is external to the device itself (its a wall wart type of power supply). You, of course, could choose to build the power supply into your device. 2 amps is the absolute minimum rating for the power supply. If all LEDs are run at full brightness, which would be blinding (think Time Square brightness), a larger power supply would be required. My Light Appliance sketch intentionally reduces the brightness of the LED panel to reduce power consumption and to keep the brightness at a level appropriate for my living room.

## SD Memory Card Preparation

The Light Appliance uses an SD memory card (2 GBytes or less) for storage of animated GIF files. The SD card is prepared as follows:

1. The SD memory card must be formatted in FAT16 format. You do this using a formatting program such as [https://www.sdcard.org/downloads/formatter\\_4/](https://www.sdcard.org/downloads/formatter_4/) or by using the file manager/explorer on your computer. Don't do a quick format; do a full format of the card.
2. Create the following directories off of the root directory of the SD card:
  1. gengifs – which will contain the general animated GIF files
  2. xmasgifs - which will contain the Christmas themed animated GIF files
  3. halogifs - which will contain the Halloween themed animated GIF files
  4. valgifs - which will contain the Valentine's day themed animated GIF files
  5. 4thgifs - which will contain the 4<sup>th</sup> of July themed animated GIF files
3. Download the file `Lindley_Animated_GIFs_Collection.zip` (see RESOURCES) and unzip it.
4. Copy the animated GIF file from the unzipped file to the corresponding directories on the SD card.

NOTE: you can add your own animated GIF files to these directories as long as they are 32x32 resolution.

## Software

The software for the Light Appliance consists of two major parts. The low level driver for the LED matrix panel and the Light Appliance sketch itself (`LightAppliance.ino` along with its associated files). The panel driver that I utilize was also written by Louis Beaudoin of [pixelmatix.com](http://pixelmatix.com). This is an amazing piece of software that allows the panel to run in 24 bit full color mode with a 120 Hz refresh rate which results in a totally flicker free display. To make things even better, the panel is driven in the background using the Teensy 3.1 Direct Memory Access (DMA) hardware which makes almost all of the micro controller's considerable processing power available to the Light Appliance application. Louis' driver also supports drawing pixels, lines, rectangles, circles, etc. to the display in addition to the low level driver functionality. High five to Louis for making the driver available to everyone on an open source basis. There are other, less capable, drivers for this panel available but this is the best one I have found for use in the Light Appliance.

All of the Light Appliance and supporting software is available free but you must still configure your development computer to be able to use it. I develop on a Mac but you can also do everything on a PC as well. Links to all of the required and optional software are listed in RESOURCES. Use the following as a check list to make sure you have all the required parts:

1. If you haven't done so already, download and install version 1.0.5 or newer of the Arduino IDE
2. Download and install the Teensyduino add on
3. Connect up your Teensy 3.1 to your development computer via a USB cable. You should see

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the LED on the Teensy blink once a second because the blink sketch is loaded into the micro controller during the manufacturing process.

4. Set the board in the IDE Tools menu to Teensy 3.1 and set the CPU speed to 96 MHZ (overclock). Pick a serial port for use with the IDE's serial monitor that is appropriate for your development computer.
5. Load the blink example sketch into the Arduino IDE. Click the verify button to compile the sketch to verify your setup.
6. Click the Upload button to program your Teensy 3.1 with the Blink sketch and verify the LED still blinks and that no errors occurred.
7. Close the Arduino IDE.
8. Insert your newly prepared SD card into its socket.
9. Download the file Lindley\_LightAppliance-PainterSketches.zip (see RESOURCES) and unzip it. Copy the LightAppliance and Painter directories into your Arduino sketch directory.
10. Download the file Lindley\_LightApplianceLibraries.zip (see RESOURCES) and unzip it. Copy the contents of the zip file into your Arduino libraries directory.
11. Restart the IDE, load the Light Appliance sketch, power up your Light Appliance and click the Upload button to program your Teensy 3.1.

If all is well you should see your display light up and be able to control your Light Appliance with the remote.

The Light Appliance sketch assumes, by default, a full hardware build. But, as previously mentioned, the Light Appliance device can be built leaving out some hardware components but modifications to the Light Appliance sketch will be required to support this. Find the following code at the top of the sketch LightAppliance.ino:

```
// Define the optional hardware. If missing hardware set value to 0
#define HAS_RTC 1
#define HAS_TEMP_SENSOR 1
#define HAS_SD_CARD 1
```

If you don't want to use the RTC, set HAS\_RTC to 0. If you don't have the temperature sensor connected, set the HAS\_TEMP\_SENSOR to 0. If you aren't going to use the SD memory card set HAS\_SD\_CARD to 0. By setting these values to zero you remove the functionality the hardware device would provide from the Light Appliance application. Removing the SD memory card functionality means the Light Appliance cannot display animations which, in my opinion, is the best feature.

If you would like to try out the Painter sketch, load it into the Arduino IDE and reprogram your Light

Appliance with it. There is a read me file in the sketch directory which details how to use the program.

## Controlling the Light Appliance

The Light Appliance is controlled via the nine button SparkFun IR remote control shown in Photo Five. The basic functions of the buttons is detailed in Table Two. Controlling the Light Appliance with the remote will become second nature after a little practice.

Table Two  
Remote Control Button Functions

Button/Key	Function
Power Symbol	If the Light Appliance is off, it turns it on. If in a submode like Patterns mode brings you back up to the main mode selection mode.
A	Used in mood light mode to turn on all LEDs
B	Used in mood light mode to turn off every second LED
C	Used in mood light mode to turn off every third LED
Up Arrow	Used to increase a value as in incrementing the minutes count of the RTC. Also used for navigation in the games.
Left Arrow	Used to select a previous function or used for navigation in the games.
Select or O	Selects the current function
Right Arrow	Used to select the next function or used for navigation in the games.
Down Arrow	Used to decrease a value as in decrementing the minutes count of the RTC. Also used for navigation in the games.

## Packaging

Being a woodworker I decided to build a custom case for my Light Appliance as can be seen in Photo Six. I had a broken display case laying around which had nicely carved wooden sides so I made my case from that.

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An off the shelf packaging alternative is an 8" x 8" black shadow box from Michaels, item# 10223090, which is almost a perfect fit. If you use the shadow box you might want to experiment putting various materials between the LED panel and the glass front to diffuse the light from the LEDs. Even a single sheet of paper has a visible effect. Drafting film could be used for even more diffusion. A sheet of thin white translucent acrylic would really blur out the display and produce some rather spacey effects.

However you decide to package your Light Appliance make sure to position the IR receiver/detector so that it is visible from where you plan on controlling your device.

## Resources

The following sources provide more information about this project and its background.

Information about getting started with the Arduino can be found at:

<http://arduino.cc/en/Guide/HomePage>. The Arduino IDE can be downloaded from:

<http://arduino.cc/en/main/software>. Note version 1.0.5 or newer of the IDE is required for use with the Light Appliance.

For information about and/or purchase of the Teensy 3.1 micro controller board go to: [www.pjrc.com](http://www.pjrc.com).

There is also a forum for information about the Teensy line of micro controllers at:

<http://forum.pjrc.com/forum.php>. Questions regarding the Teensy should be directed there.

The Teensyduino (version 1.18 or newer) software development add on to the Arduino IDE is available at: [www.pjrc.com/teensy/teensyduino.html](http://www.pjrc.com/teensy/teensyduino.html) as are instructions for installing it.

Information about the SmartMatrix kit and/or the SmartMatrix driver can be found at:

[www.pixelmatix.com](http://www.pixelmatix.com). The most current version of the driver is available at:

<https://github.com/pixelmatix/SmartMatrix>.

The collection of animated GIF files for the Light Appliance is contained in a file called

[Lindley\\_Animated\\_GIFs\\_Collection.zip](#). The Light Appliance and Painter sketches are contained in a file called [Lindley\\_LightAppliance-PainterSketches.zip](#). The libraries required for the Light Appliance are contained in a file called [Lindley\\_LightApplianceLibraries.zip](#). These files should be available for download from the Nuts and Volts website or from [craigandheather.net/misc](http://craigandheather.net/misc).

For a look at the blog that started this project off see:

<http://dangerousprototypes.com/forum/viewtopic.php?f=56&t=6125&p=56311>.

Jason Coon ported the computer games to the Light Appliance.

Other micro controller based projects of mine can be found at:

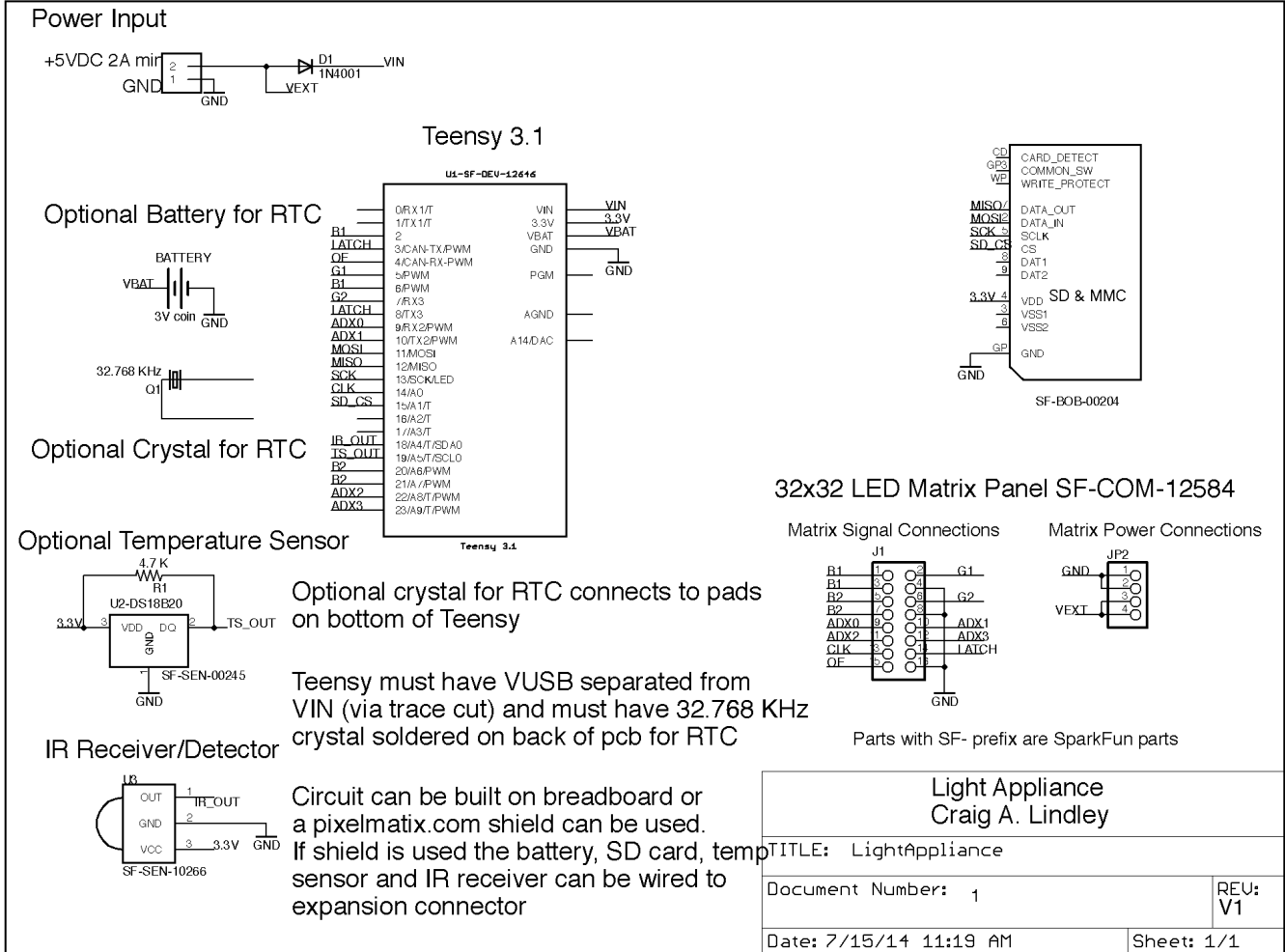
[www.craigandheather.net/celepage.html](http://www.craigandheather.net/celepage.html).

For background information about GIF files, computer graphics and image processing see my book:

“Practical Image Processing in C”, published by John Wiley & Sons. This book is out of print but used copies are available from many sources.

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Figure One  
Schematic Diagram





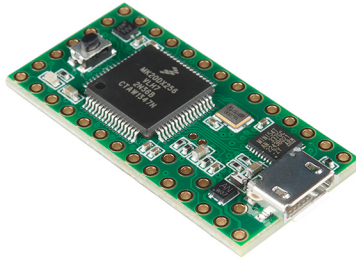
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Figure Two  
Parts List

Part Description	Source
32x32 RGB LED Matrix Panel comes with ribbon and power cables	SparkFun part number: COM-12584; Adafruit part number: 1484
Teensy 3.1 micro controller	www.pjrc.com; SparkFun part number: DEV-12646; Adafruit part number: 1625
SmartMatrix Shield Kit for Teensy 3	pixelmatix.com; Adafruit part number: 1902
5 volt 2 amp (min) power supply	SparkFun part number: TOL-12889; Adafruit part number: 276
DS18B20 optional temperature sensor requires 4.7K ¼ watt 5% resistor if temperature sensor is used	SparkFun part number: SEN-00245; Adafruit part number: 374
IR Receiver/Detector	SparkFun part number: SEN-10266; Adafruit part number: 157
32.768 KHz crystal 12.5 pF optional crystal for Teensy RTC	SparkFun part number: COM-00540; Digikey part 300-8303-ND, 300-8762-ND, 300-8763-ND, or 300-1002-ND
3 volt battery and battery holder optional for Teensy RTC	Can be a coin battery such as CR-2025 or CR-2032 or a couple of AA or AAA batteries
SD/MMC memory card breakout PCB	SparkFun part number: BOB-00204, BOB-12941 or equivalent
SD memory card up to 2 GBytes	Anywhere
IR remote control	SparkFun part number: COM-11759 Make sure to get a CR-2025 coin battery for the remote because it doesn't come with one.

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Photo One  
A Teensy 3.1 Micro Controller



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Photo Two  
32x32 RGB LED Matrix Panel  
Front View

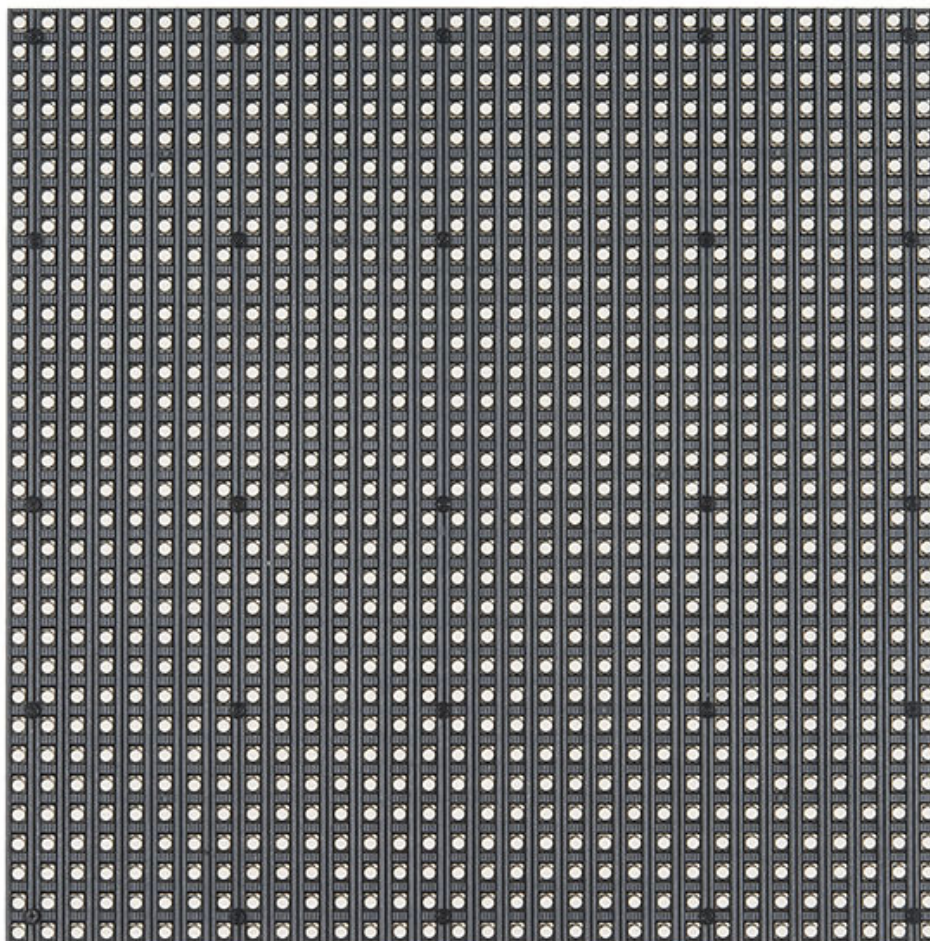
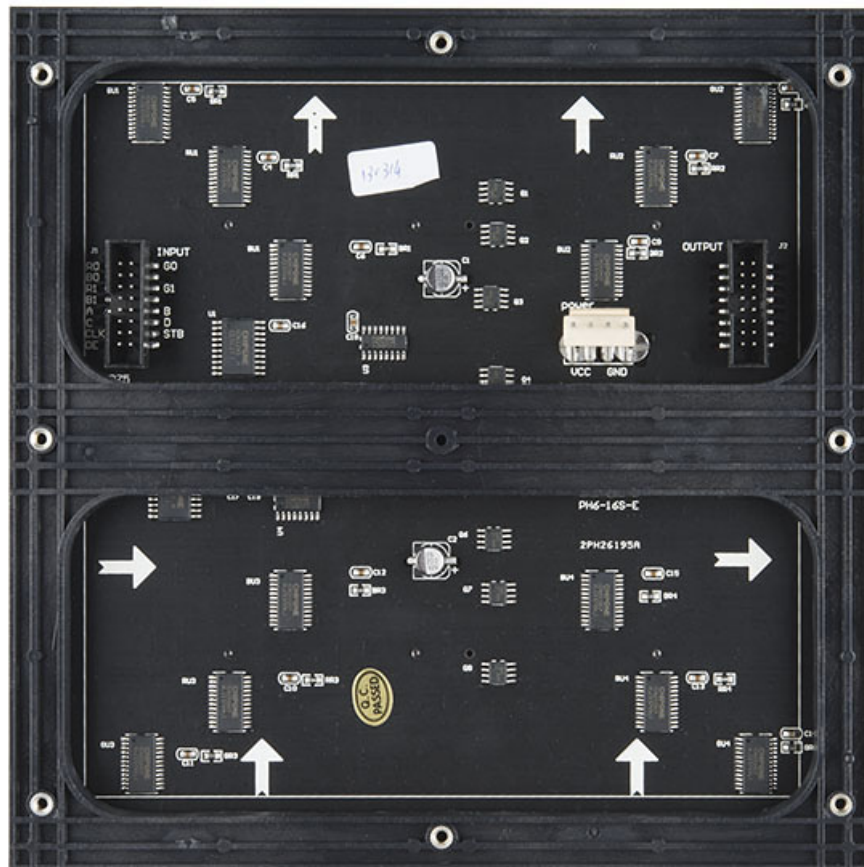


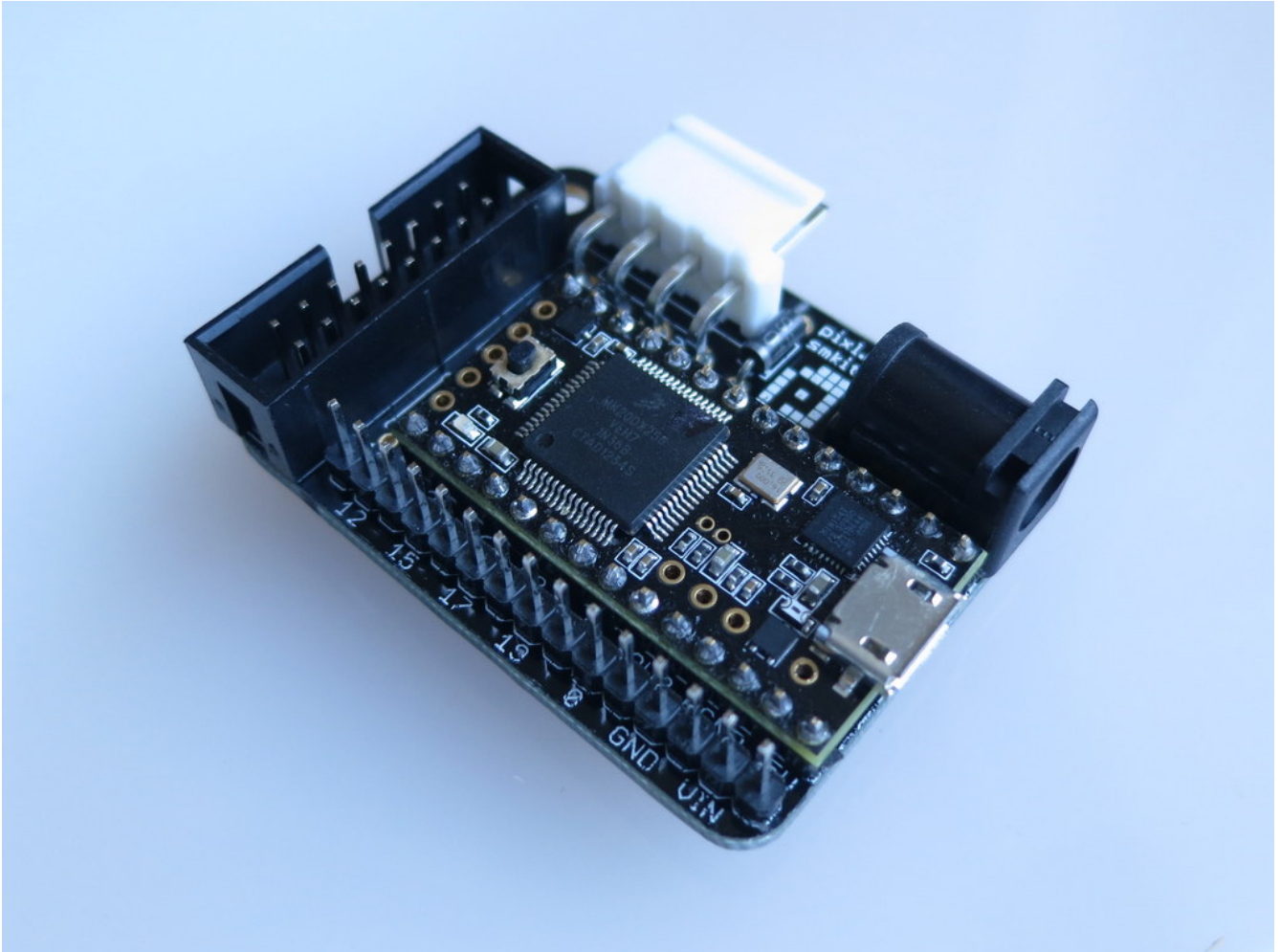
Photo Three  
32x32 RGB LED Matrix Panel  
Rear View



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Photo Four

Assembled SmartMatrix Shield from pixelmatix.com with Teensy 3.1 controller installed.  
Expansion connector in foreground



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Photo Five  
SparkFun IR Remote Control



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Photo Six

My Light Appliance

NOTE: IR Receiver/Detector shown on left middle

