Design aspects

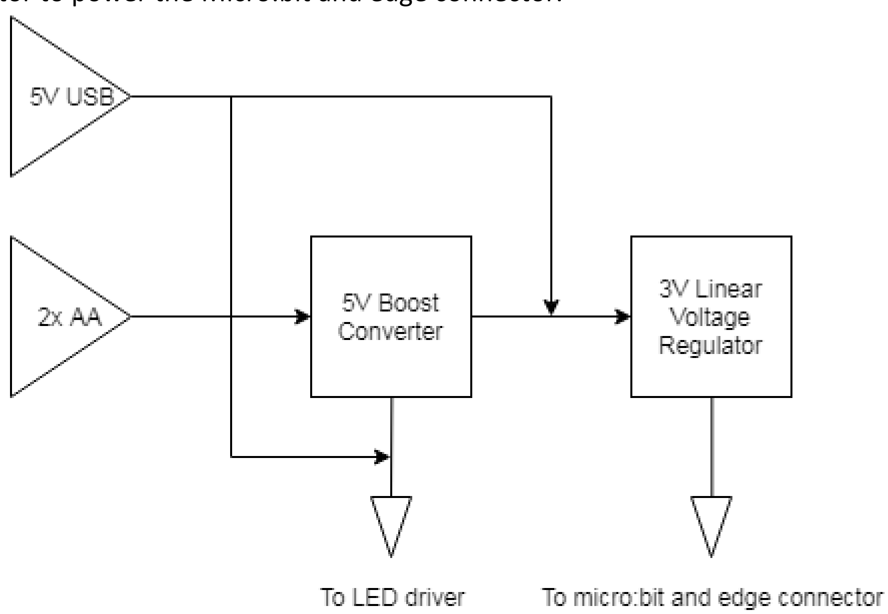
Power

The Micro:bit requires 3.3V to be powered via the edge connector, however, the HT16K33 LED driver requires 4.5-5.5V in order to work correctly.
A few ideas were considered to have a battery powered option as well as USB to power the circuit. We had initially begun designing based on 4xAA batteries (6V) being stepped down to 5V through a linear voltage regulator. However, it was soon made clear that there are multiple problems with this design:

- Linear voltage regulators generally require ~2V above the desired output voltage to work correctly.
- If the batteries discharge below 5V, the output will always be below 5V.

A Buck converter was then considered, but this also suffered from the problem whereby if the 4xAA voltage discharges below 5V, the output cannot match the desired 5V as a buck converter can only step down.
We then decided to go with a 2xAA 3V configuration using a boost converter to step up the voltage to 5V.
A boost topology converter was used to step up the ~3V from the 2xAA batteries to 5V in a closed loop configuration. This allows for the largest range of discharge in the batteries as the boost converter can function until the 2xAA drops to round 1.4V.

With USB power, the 5V can directly go to power the LED driver whilst being fed through a 3.3V linear voltage regulator to power the Micro:bit and edge connector.



A consideration that needs to be investigated is the amount of current being drawn from the batteries in order to allow this step-up to occur at low battery voltages. It could lead to a runaway situation in battery discharging and overheating.

Another idea was to have a switch to choose between power supplies. This avoids the potential danger of having both the USB and batteries connected at the same time.

This has been implemented via a DPDT on-off-on switch. When in position one, the USB is connected directly to the 5V rail of the circuit. When in the middle position, the mega bit is off. When in position 3, the batteries are connected to the input of the Boost converter.

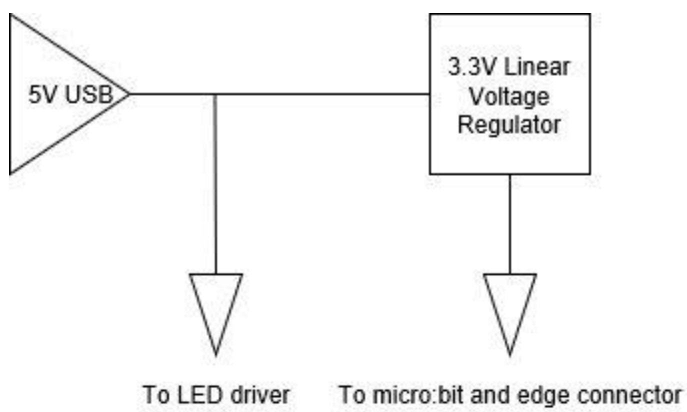
PCB Revision 1

The revision 1 PCB is a small version of the Megabit used to test our design. It will have the core functionality of the desired end product purely to ensure that we have a working foundation to build upon in future revisions, which will have more features and be more complex.

The main design decisions and rational are shown below:

Decision: 5v USB power ONLY through an external breakout board

Rational: Battery powered operation requires lots of external circuitry in order to work. The USB header also uses extremely small and awkward to solder surface mount pins. We therefore decided to omit the battery powered portion of the circuit and opt for a USB breakout board package to minimise the amount of time wasted on soldering. It is currently expected that the battery supply will be included on the 2nd revision, however this is subject to change following market research.



Decision: 28-pin LED driver chip used instead of 24-pin that was used in the proof of concept.

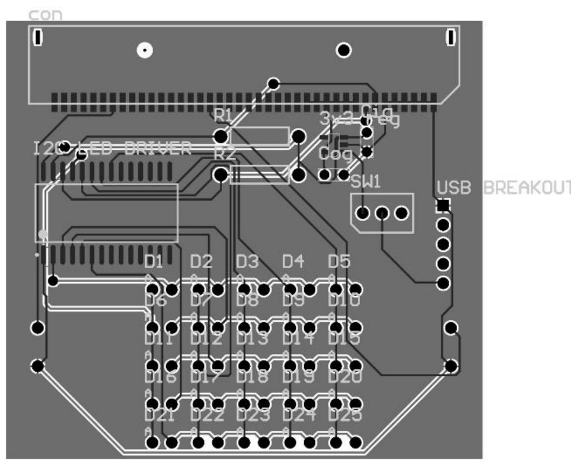
Rational: When coming to order the LED chip, it was discovered that the 24-pin version of the chip was not easily orderable through Imperials trusted suppliers. We therefore were forced to use the 28-pin version, which will mean that some software changes will be necessary.

Decision: L-793SRD 8 mm round super bright red LED

Rational: The LEDs were chosen to be bright and large so that these are visible over large distances.

Decision: Layout of the PCB compressed to 62 x 57 mm.

Rational: As this is a testing board and manufacturing single PCBs have a high cost, we tried to keep the PCB as small as possible while having the most functional and visually appealing display. Hence, the header is at the top where the micro: bit would be connected, followed by the LED driver and pull-up resistors; the micro USB port is located on the side for an easier access and below the LED matrix with the two buttons on the side.



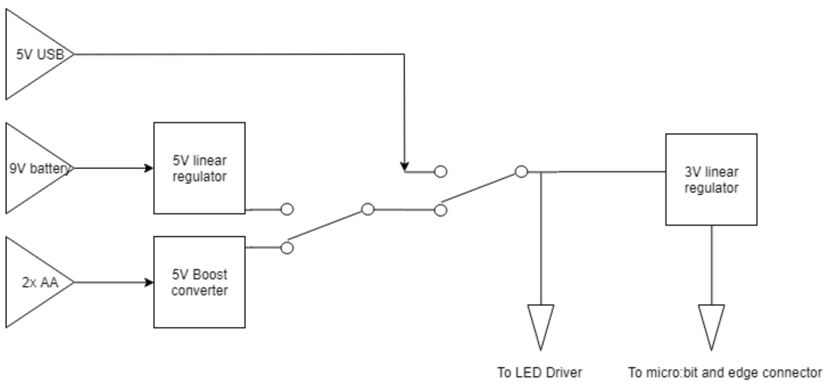
Conclusion:

The first revision PCB worked well, despite the spacing for the LEDs being too small and having to make an external stripboard LED matrix. The next steps were now to think about additional powering methods.

The LED stripboard matrix was tested across the whole length of the Level 1 labs (30-50 meters) and was well visible at all distances. We are therefore pleased with the brightness and visibility performance of the LEDs.

PCB Revision 2

After the success of the first PCB and discussing with our client, we decided to build a second revision with an added power option to test, namely a 9V and 2xAA battery power.

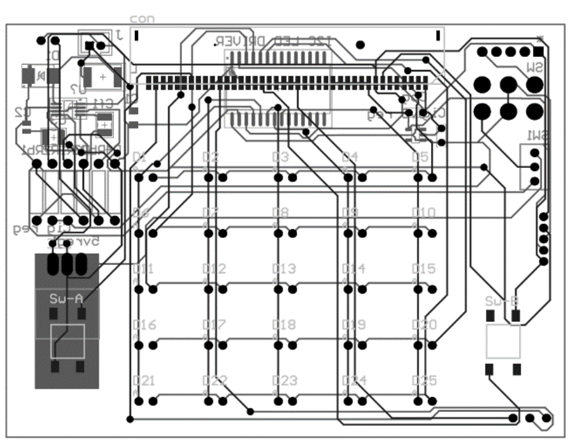


The purpose of this was mainly to test the different battery powered solutions that we had in mind. Each way of providing 5V is isolated with a switch and so can be disabled if it doesn't work as intended.

We decided to use proper switches and the correct spacing for LEDs in this revision, as well as adding in test points to measure the SCL, SDA and +5, +3.3 points.

Pads for the large edge connectors were also added.

We chose to place all the components on the rear of the PCB and the interface controls and LEDS on the front to mimic what we would like the megabit to be in the end. The ground plane was removed to help with soldering but may well be re-introduced in the final revision.



Conclusion:
We found that the 9V battery power worked well and is a feasible way to power the circuit, however we are concerned about power consumption. Something noticed was that when the megabit was not plugged in, the battery and 5v regulator were warm, likely to be due to the linear regulator being designed to run at a higher input voltage.
It was decided that in the final PCB we shall use a USB and 9V supply, assuming there is not a better

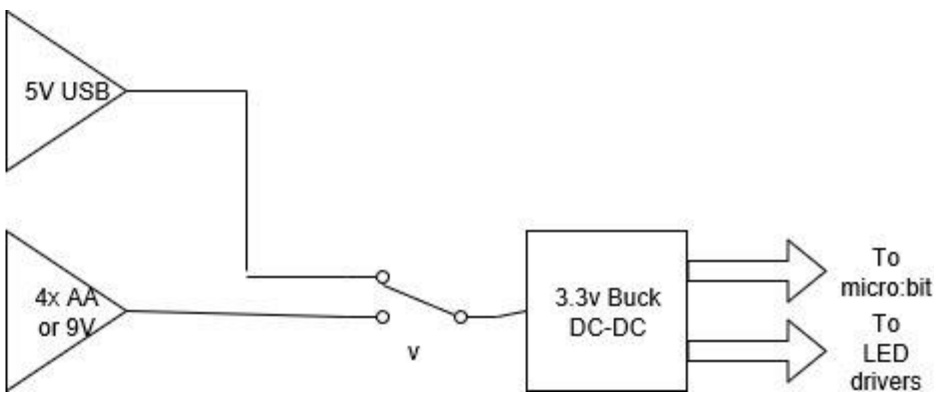
battery supply available. The boost circuit was unable to be tested due to inconsistencies in the PCB footprints and what was received, however we decided that it is not worth pursuing anyway.

PCB Revision 3

The revision 3 board was primarily made to test a different method of LED driving that allows for individual LED brightness control. Two 16-channel LED driver chips (32 total to have a 25-LED matrix) are used on the same I2C bus. An added benefit is that these chips are able to run off 3.3V, removing the need for any 5v regulation.

The board is also to be used in testing a Buck DC-DC converter which, if works, will remove the need for a linear 3.3V regulator and increase efficiency in the circuit greatly, which is important for battery powered operations.

A diagram of the revision is shown below:



It is expected that the final Megabit will be using the 5v HT16K33 chip rather than a different type of chip which is able to run off 3.3V. In this case, the 4xAA will be omitted and only a 9V battery can be used. This is so that a 5V linear regulator can be used which requires Vin > 6V.

Main PCB

The main PCB will have the core functionality plus any extra features that we feel add value to the product whilst retaining its simple interface and teaching value.

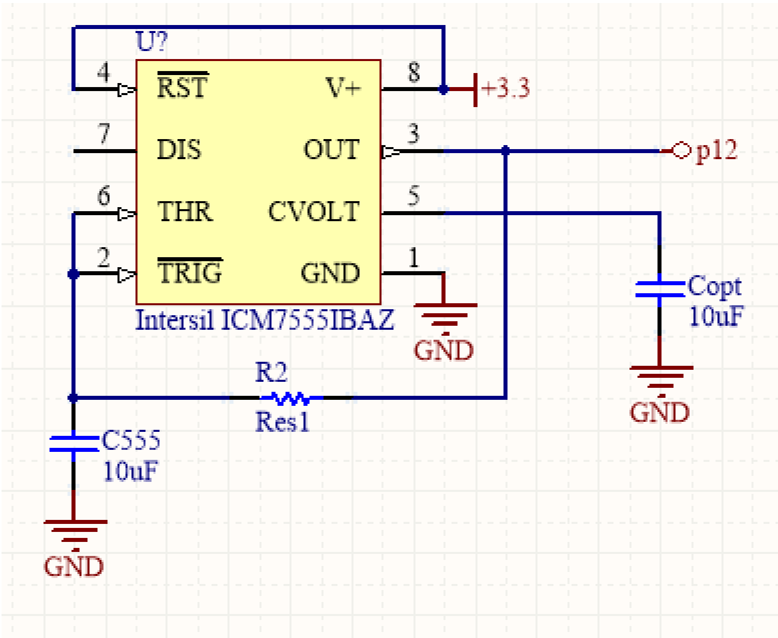
<u>Handshake</u>

In order for the micro:bit to sense whether it is plugged into the mega:bit, we devised a simple handshake in order for the megabit to ‘communicate’ with the microbit to tell it that it is connected.

The way that this works is with a simple and cheap to manufacture 555 square wave oscillator which sends a 1kHz square wave to the accessibility pin of the micro:bit.

When the micro:bit is powered on, it looks to see if the handshake is present. If it is, it then looks to see which I2C address is being used and uses this address to send the LED matrix data.

If the handshake is not present, then any addresses used on the I2C bus are assumed to be normal peripherals and not the mega:bit.



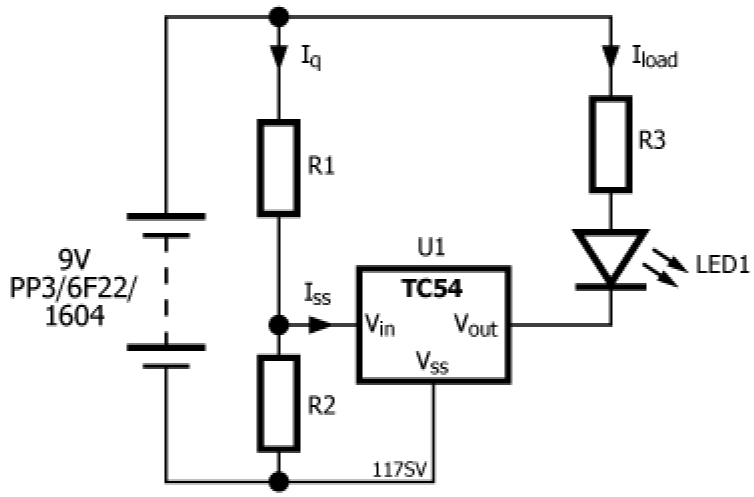
Where p12 is the accessibility pin.

Battery indicator

To indicate the voltage status of the 9 V battery source, it would be helpful to know when it presents low voltage as the linear regulator requires at least 7 V of input voltage to properly work. Hence, we have added two extra indicators:

A) **Power On indicator**: a simple 3 mm green LED that connects to the voltage source.

B) **Low battery indicator**: R1 and R2 form a potential divider that would set the voltage threshold of the following BJT. R3 works as an electrical insulator for the current. In this case, when the source voltage is less than 7.2 V, the red LED would turn on to suggest a change of battery and be off when it's located above that threshold.



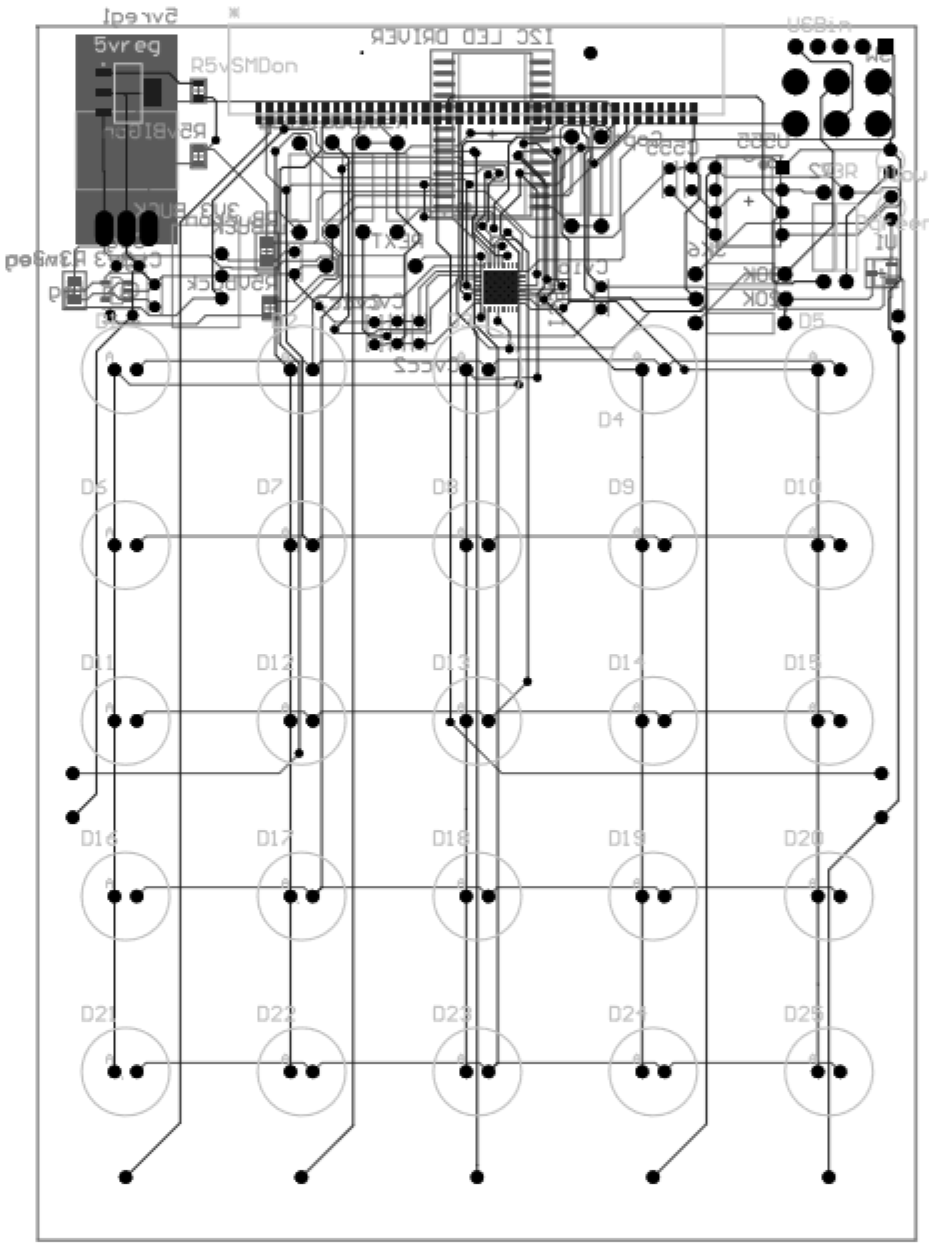
Unfortunately due to time constraints with late PCB delivery, we were unable to make the new ISSI LED driver chip work which is expected to be a software issue rather than hardware.

This PCB also had lots of extra routing for the added redundancy, which was in fact not necessary in the end, and so a revision 2 of the final megabit could be much simpler with larger tracks to reduce the difficulty with soldering and room for error.

Conclusions:

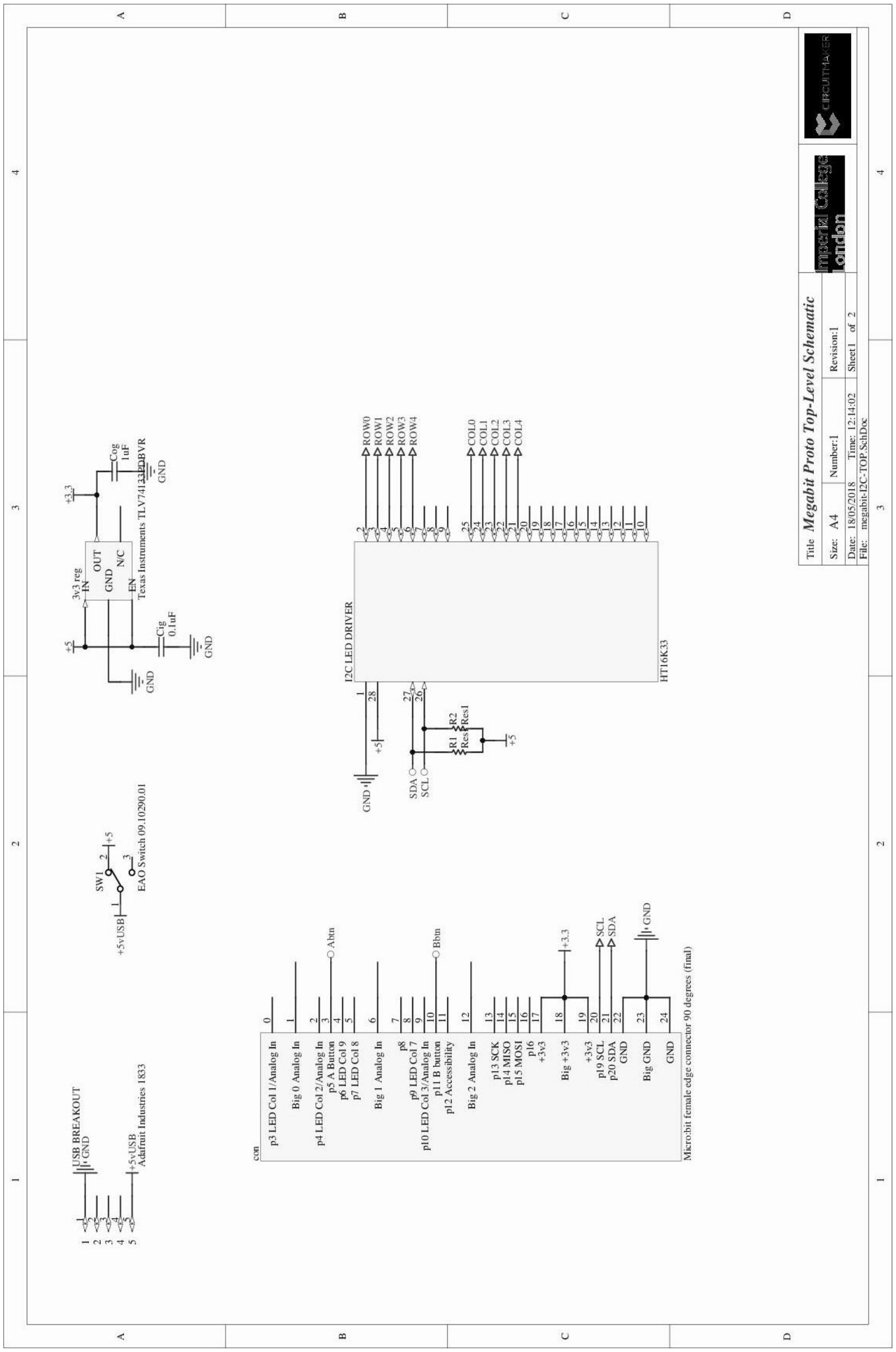
The handshake circuitry works well and only has a negligible impact on the startup of the micro:bit. The main issue with the circuitry however was that it is easy for the frequency to be changed by adding capacitance unintentionally such as by just holding the pcb. A possible fix for this is to buy a dedicated frequency generating chip which are more robust as opposed to just a general purpose 555.

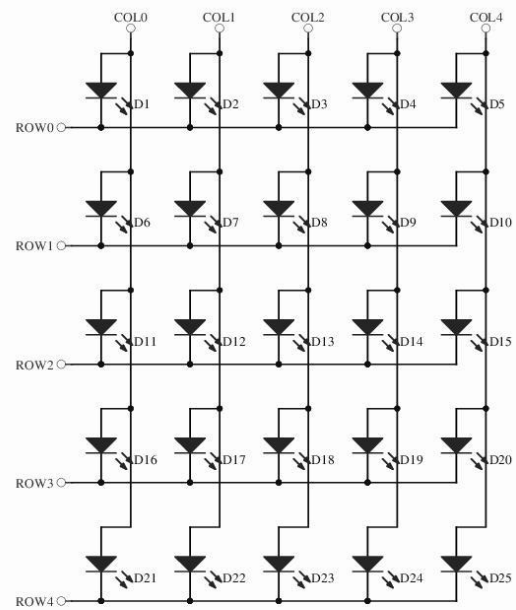
A final revision has been started which removes all the unnecessary components, however the 555 chip should be changed to a more suitable unit and everything else should be made surface mount to make mass production easier.


5vreg
R5vSMDon
USBin
D4
D5
D6
D7
D8
D9
D10
D11
D12
D13
D14
D15
D16
D17
D18
D19
D20
D21
D22
D23
D24
D25

Appendix

Revision 1 Schematic and PCB





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Size: A4	Number:1	Revision:1
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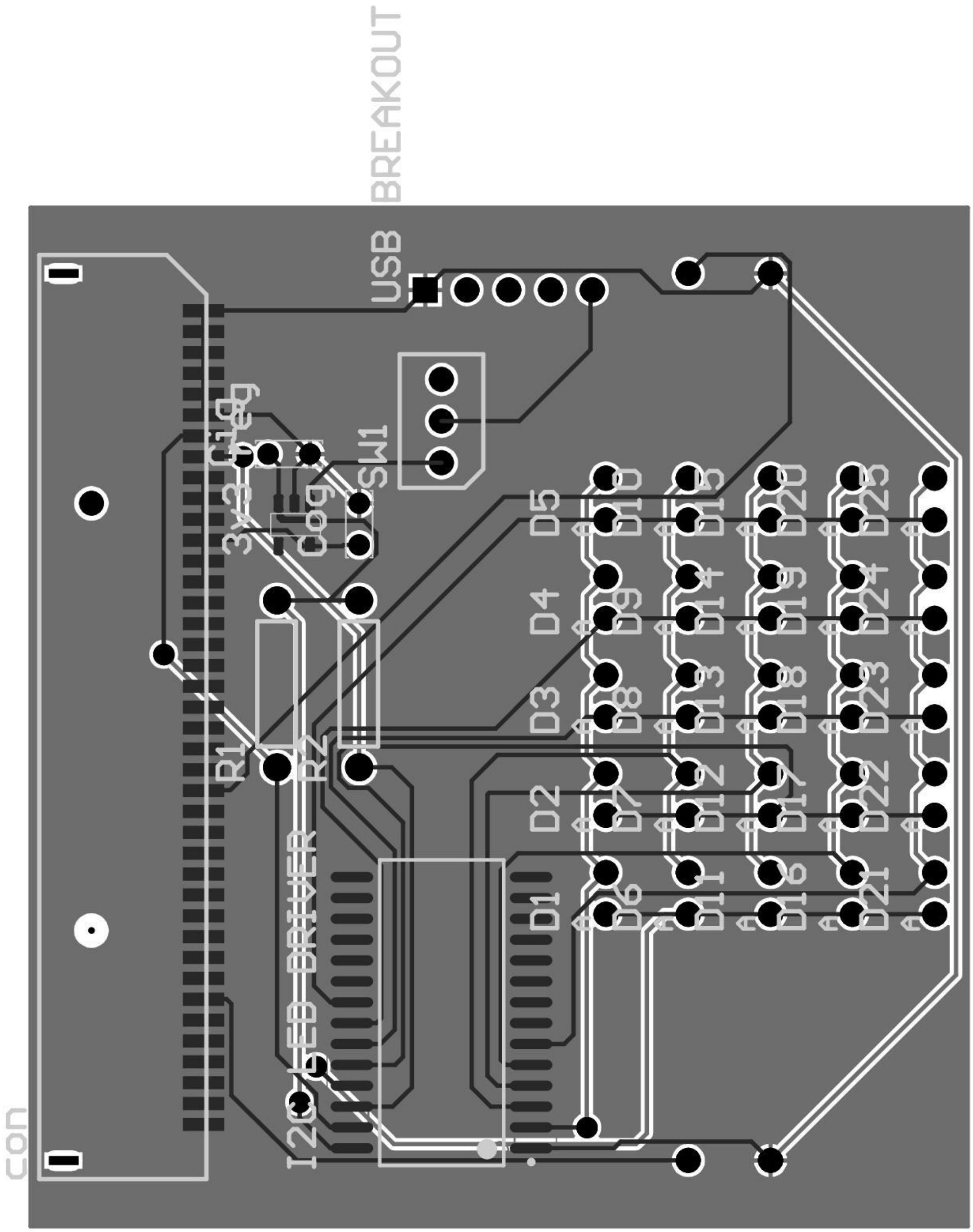
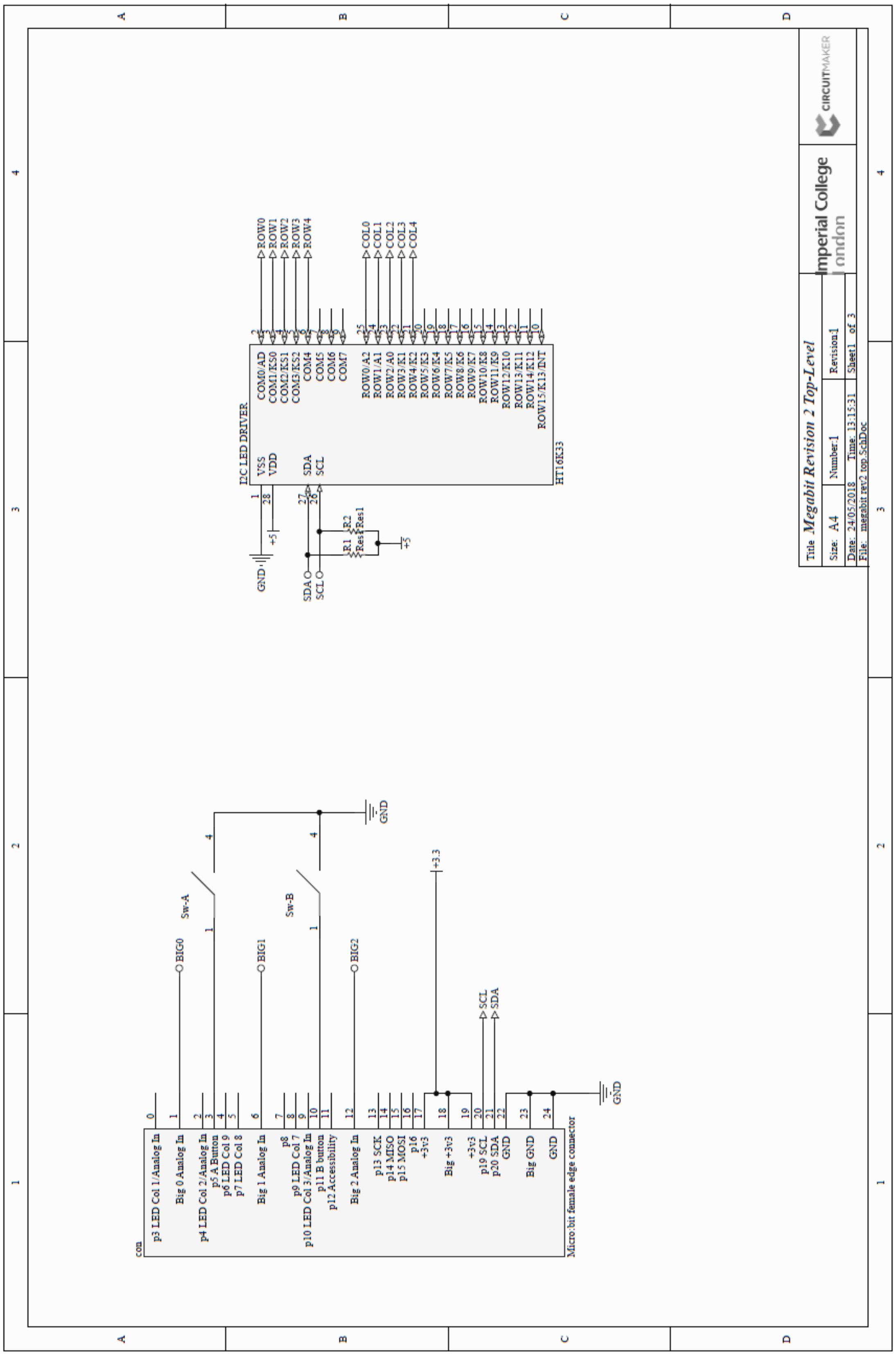
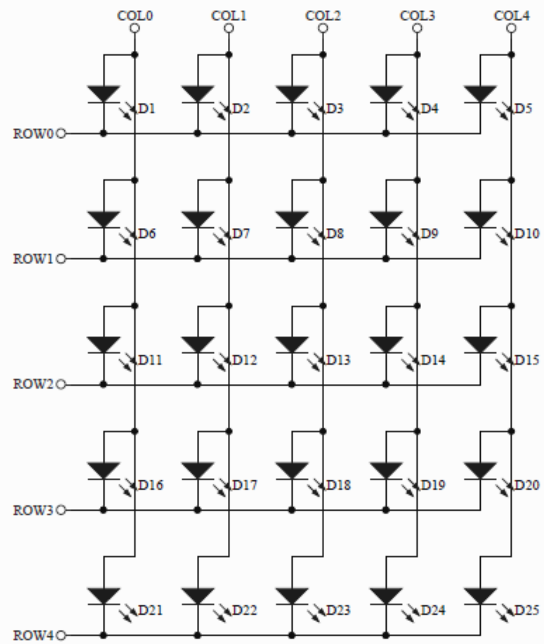
File: LED matrix.SchDoc		



USB BREAKOUT
con
SW1
3v3
R1
R2
LED DRIVER
I2C
D1
D2
D3
D4
D5
D6
D7
D8
D9
D10
D11
D12
D13
D14
D15
D16
D17
D18
D19
D20
D21
D22
D23
D24
D25

Revision 2 Schematic and PCB





Title *Megabit LED Matrix*		
Size: A4	Number:2	Revision:1
Date: 24/05/2018	Time: 13:15:31	Sheet2 of 3
File: LED matrix.SchDoc		

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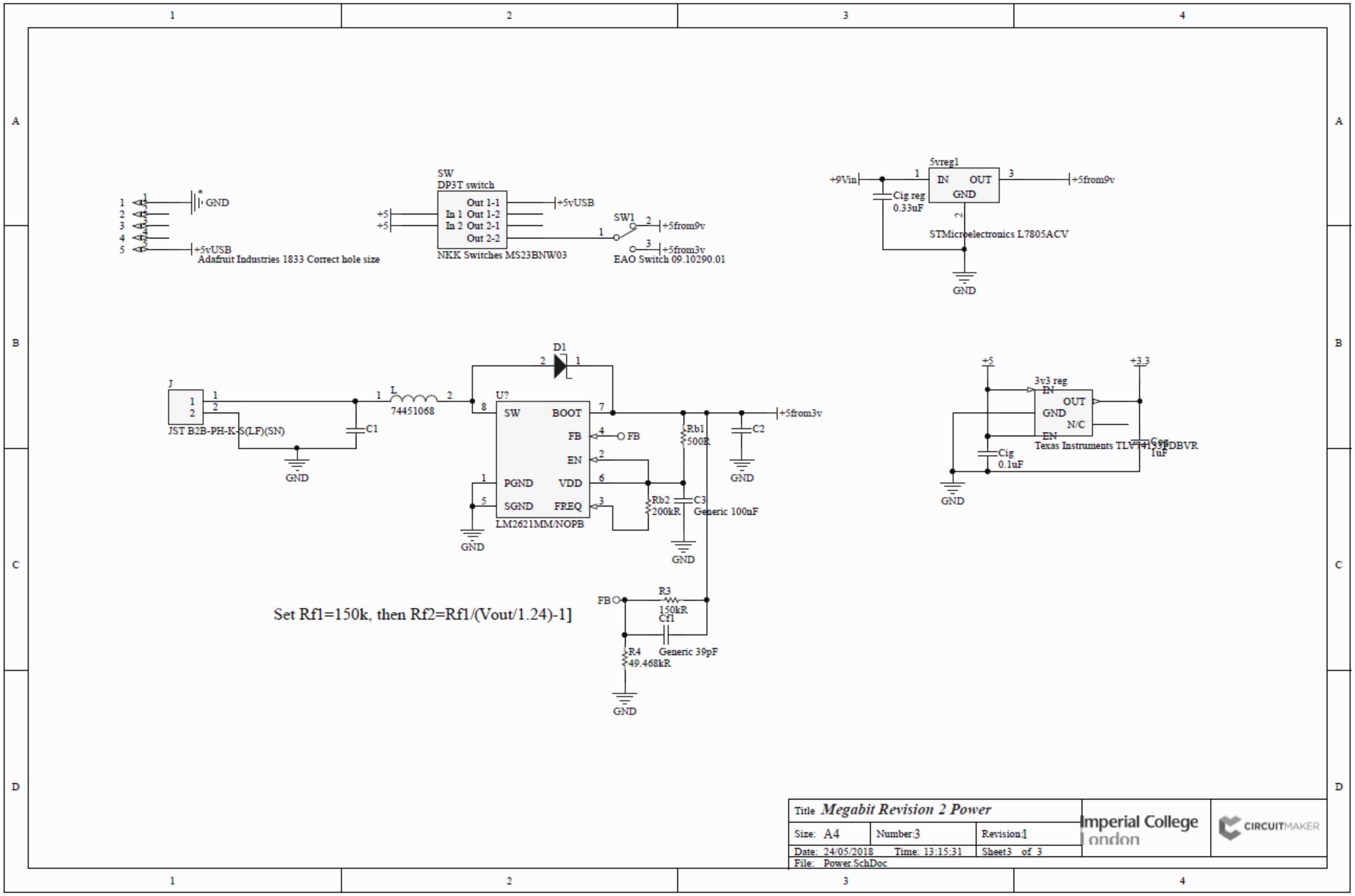
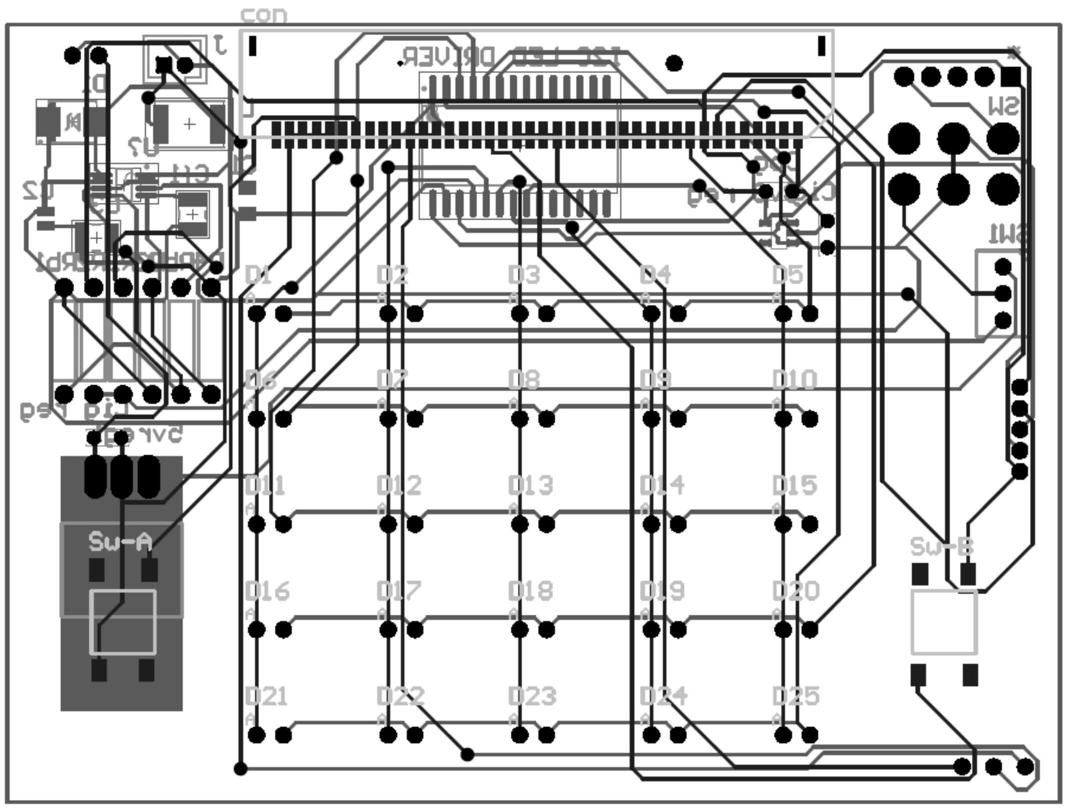
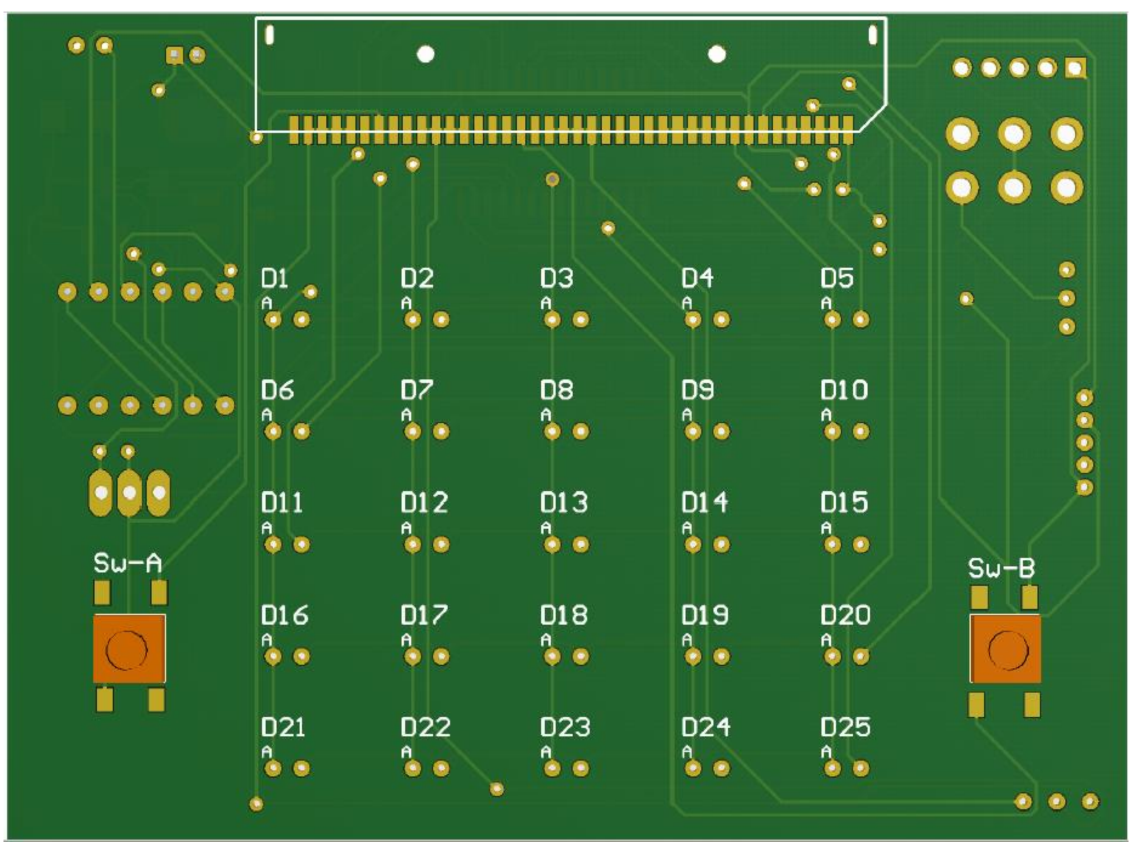
CIRCUITMAKER

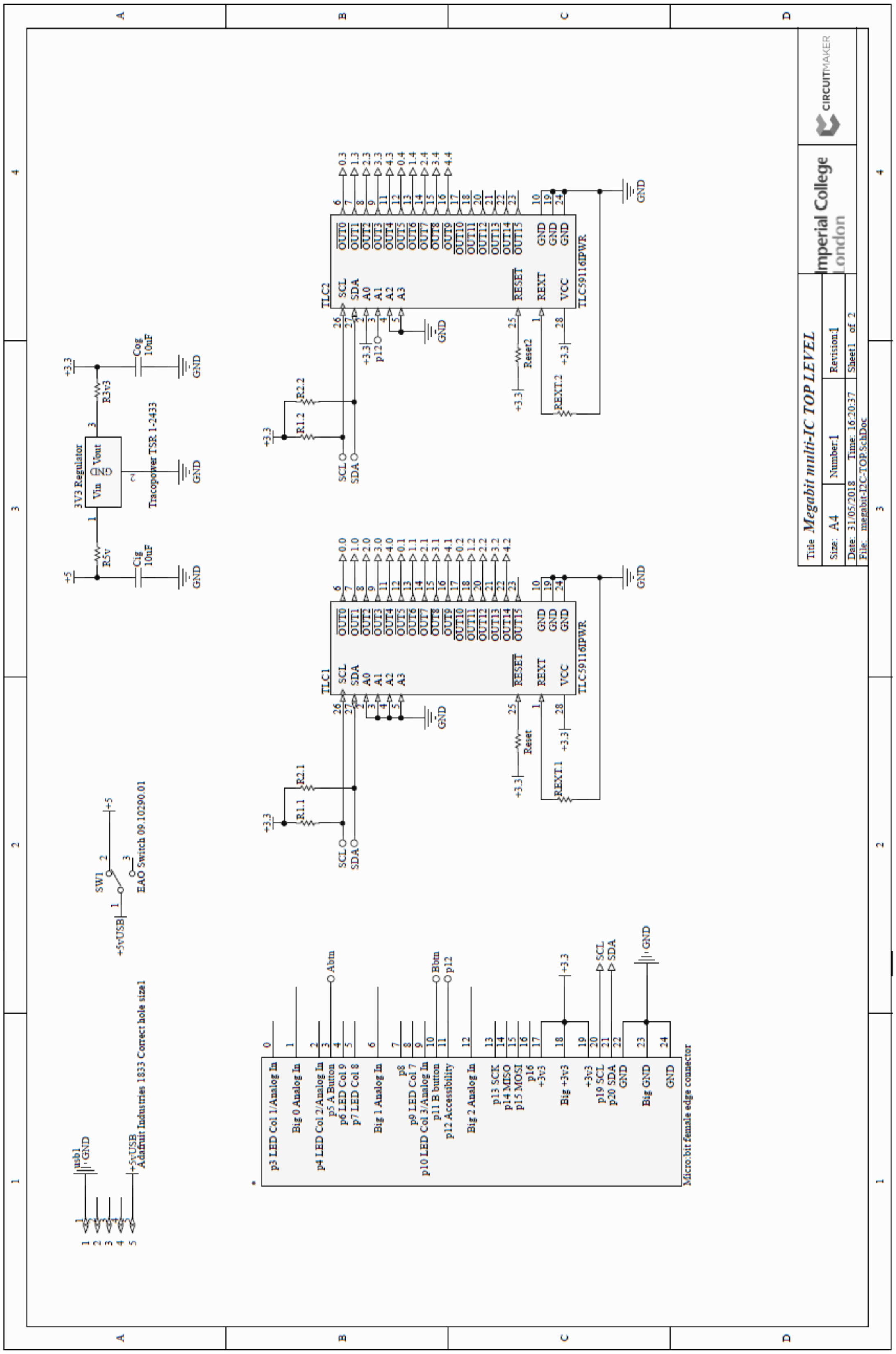


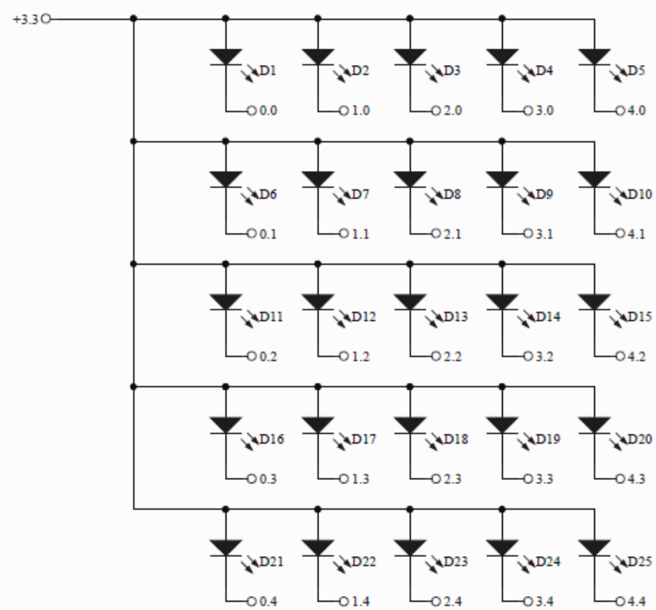
GND
+5vUSB
Adafruit Industries 1833 Correct hole size
SW
DP3T switch
In 1
In 2
Out 1-1
Out 1-2
Out 2-1
Out 2-2
NKK Switches MS23BNW03
+5
+5
SW1
+5from9v
+5from3v
EAO Switch 09.10290.01
+9Vin
5vreg1
IN
OUT
GND
Cig reg
0.33uF
STMicroelectronics L7805ACV
J
JST B2B-PH-K-S(LF)(SN)
C1
L
74451068
D1
U?
SW
BOOT
FB
EN
PGND
VDD
SGND
FREQ
LM2621MM/NOPB
Rb1
500R
Rb2
200kR
C3
Generic 100nF
C2
R3
150kR
Cf1
Generic 39pF
R4
49.468kR
+5
+3.3
3v3 reg
N/C
Cig
0.1uF
Cog
1uF
Texas Instruments TLV74133PDBVR
Set Rf1=150k, then Rf2=Rf1/(Vout/1.24)-1]
Title Megabit Revision 2 Power
Size: A4
Number:3
Revision:1
Date: 24/05/2018
Time: 13:15:31
Sheet3 of 3
File: Power.SchDoc
Imperial College London
CIRCUITMAKER


con
D1
D2
D3
D4
D5
D6
D7
D8
D9
D10
D11
D12
D13
D14
D15
D16
D17
D18
D19
D20
D21
D22
D23
D24
D25
Sw-A
Sw-B


D1
D2
D3
D4
D5
D6
D7
D8
D9
D10
D11
D12
D13
D14
D15
D16
D17
D18
D19
D20
D21
D22
D23
D24
D25
Sw-A
Sw-B

Revision 3 PCB and schematic





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File: LED matrix.SchDoc		

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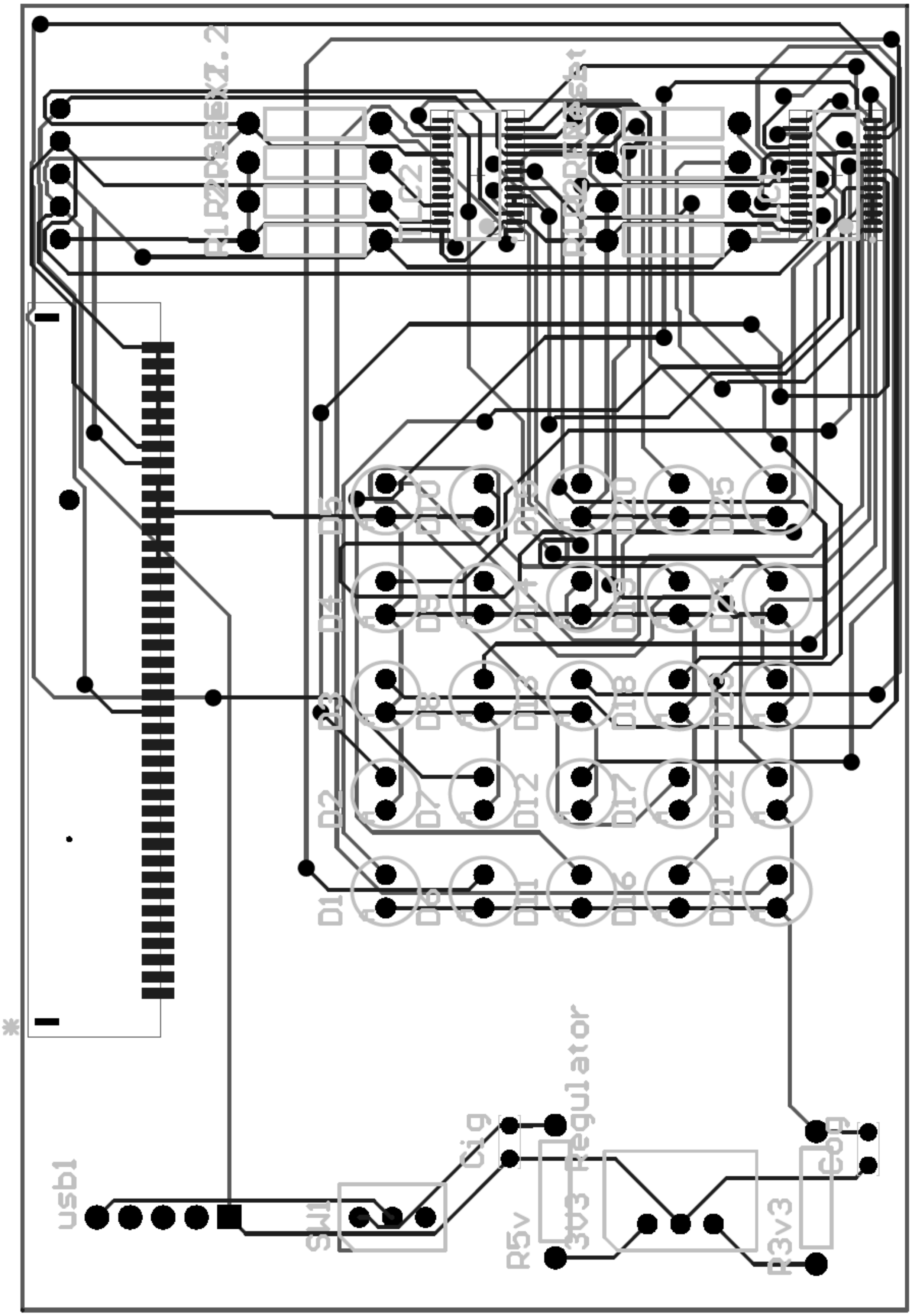
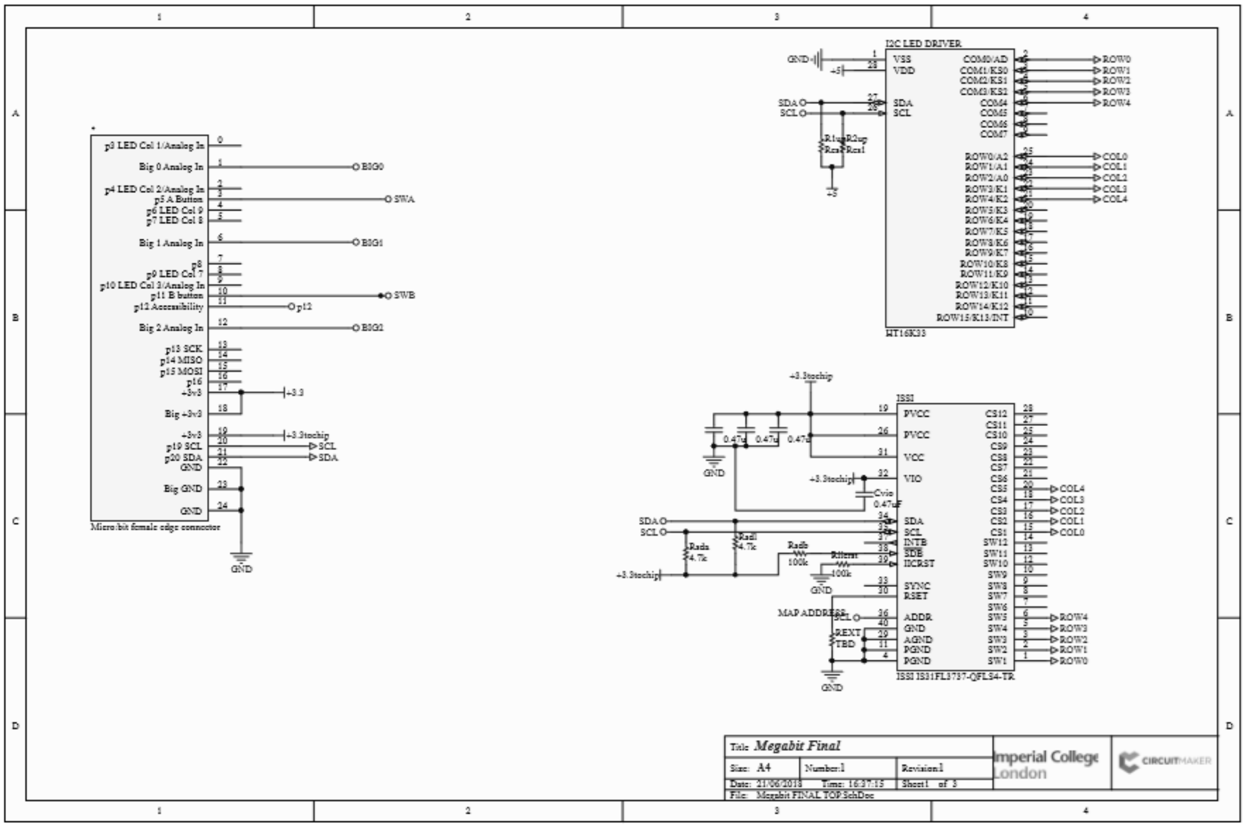
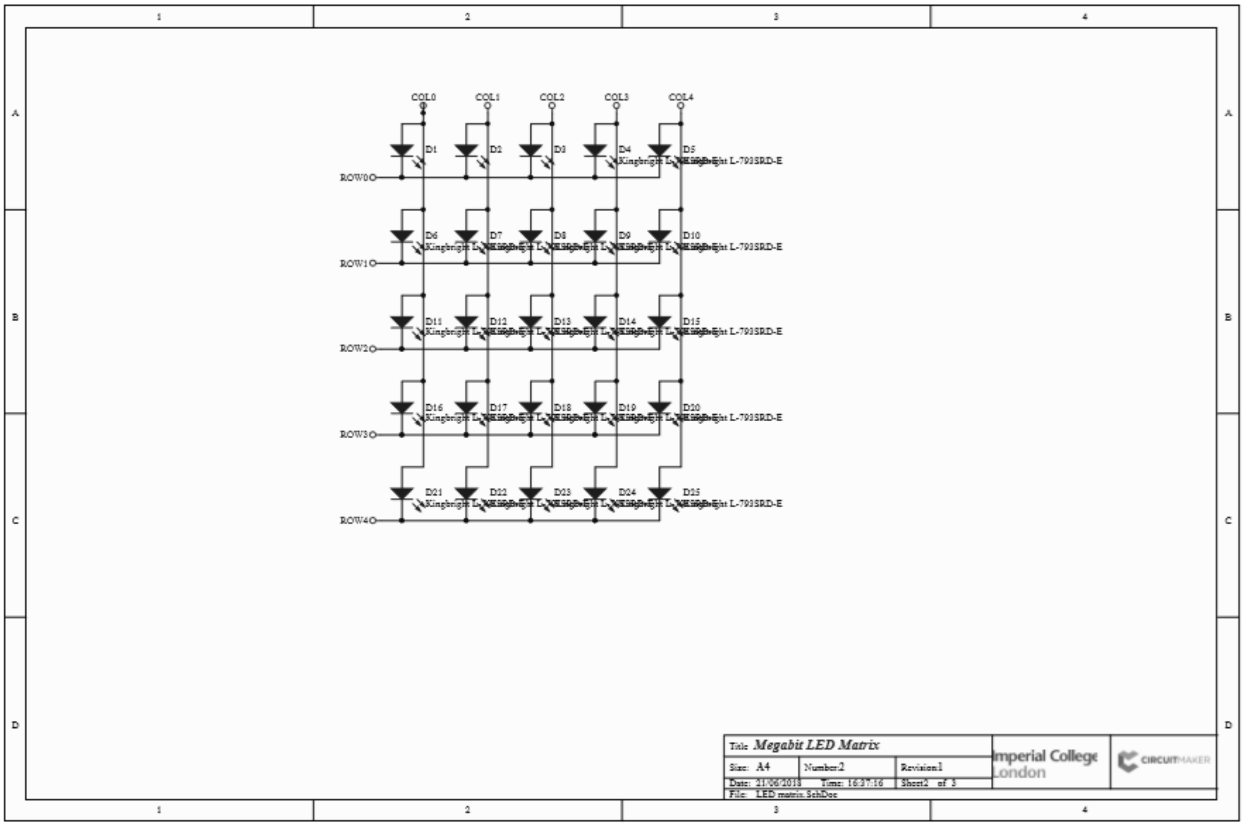

usb1
SW1
Cig
Cog
R5v
3v3 Regulator
R3v3
D1
D2
D3
D4
D5
D6
D7
D8
D9
D10
D11
D12
D13
D16
D17
D18
D21
D22
D23
D24
D25
IC2
IC1

Megabit Final Schematics and PCB




COL0
COL1
COL2
COL3
COL4
ROW0
ROW1
ROW2
ROW3
ROW4
Kingbright L-793SRD-E
Title Megabit LED Matrix
Size: A4
Number:2
Revision:1
Date: 21/06/2018
Time: 16:37:16
Sheet2 of 3
File: LED matrix.SchDoc
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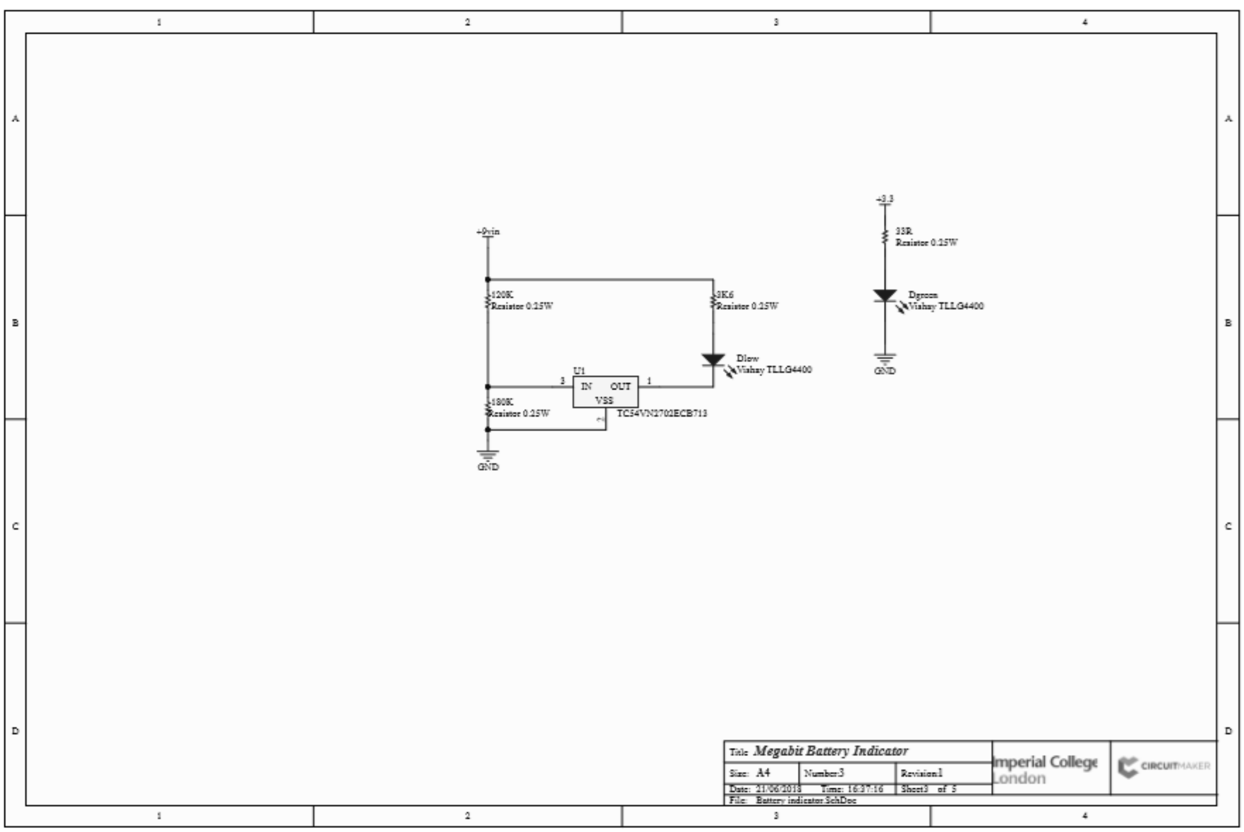
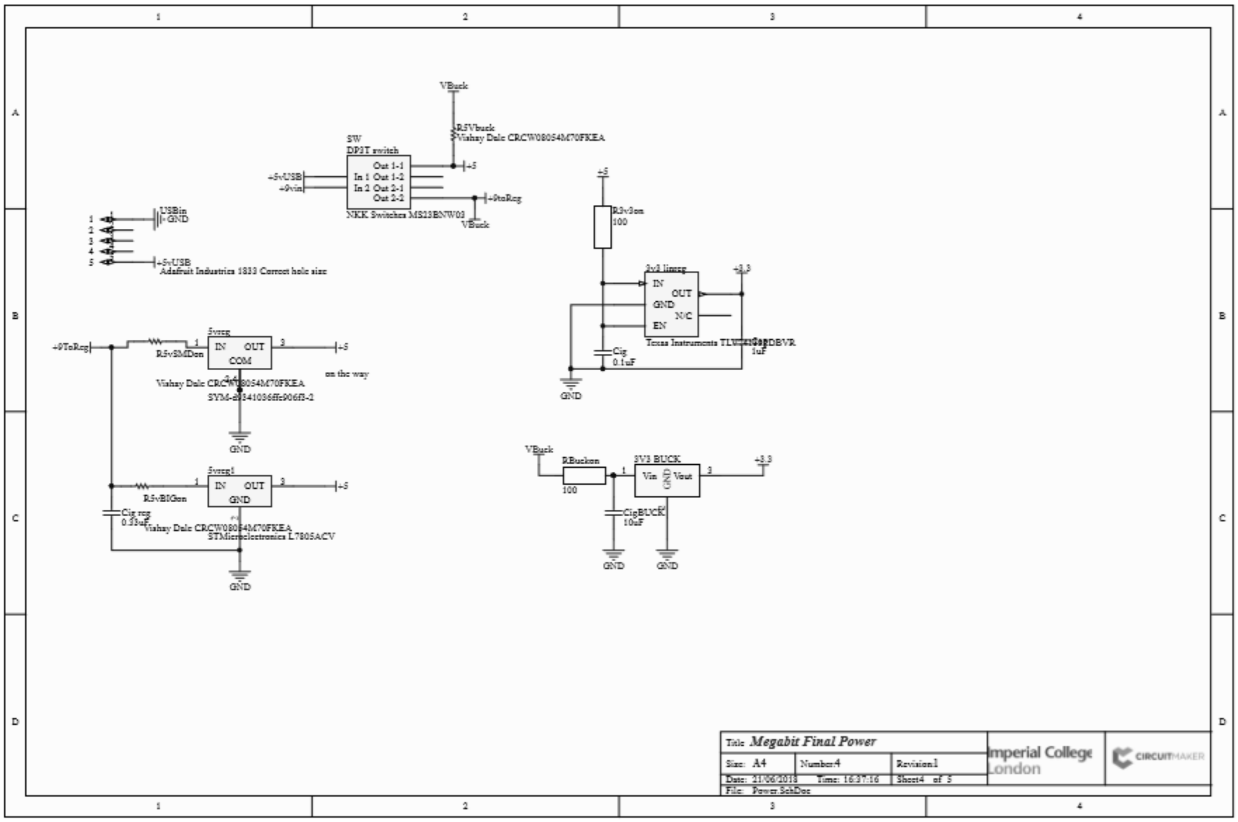
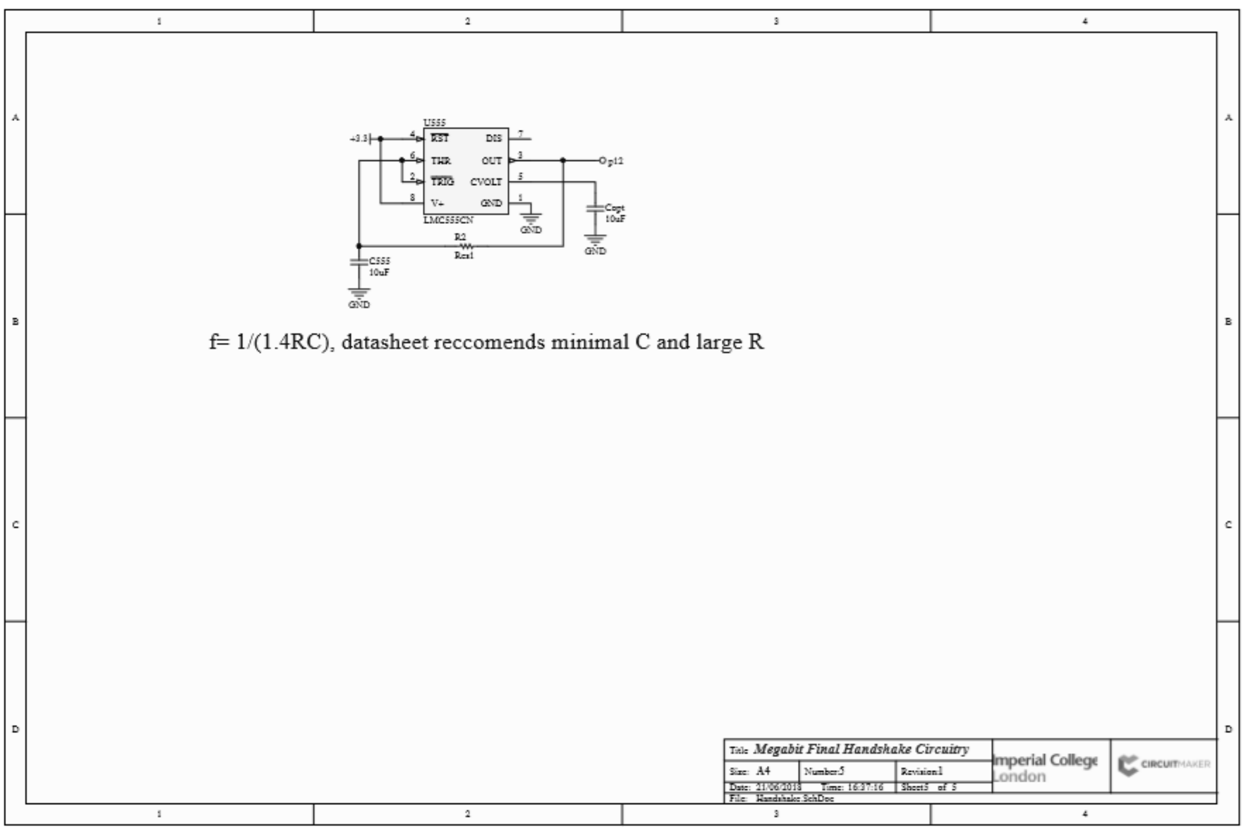

+9vin
120K
Resistor 0.25W
180K
Resistor 0.25W
3K6
Resistor 0.25W
U1
IN
OUT
VSS
TC54VN2702ECB713
Dlow
Vishay TLLG4400
GND
+3.3
33R
Resistor 0.25W
Dgreen
Vishay TLLG4400
GND
Title Megabit Battery Indicator
Size: A4
Number:3
Revision:1
Date: 21/06/2018
Time: 16:37:16
Sheet3 of 3
File: Battery indicator.SchDoc
Imperial College London


VBuck
R5Vbuck
Vishay Dale CRCW08054M70FKEA
SW
DP3T switch
+5vUSB
+9vin
In 1 Out 1-1
Out 1-2
In 2 Out 2-1
Out 2-2
NKK Switches MS23BNW03
+5
+9toReg
VBuck
USBin
GND
+5vUSB
Adafruit Industries 1833 Correct hole size
R3v3on
100
3v3 linreg
IN
OUT
GND
N/C
EN
+3.3
Texas Instruments TLV
Cig
0.1uF
1uF
GND
+9ToReg
R5vSMDon
5vreg
IN OUT
COM
+5
on the way
Vishay Dale CRCW08054M70FKEA
GND
5vreg1
IN OUT
GND
R5vBIGon
Cig reg
0.33uF
Vishay Dale CRCW08054M70FKEA
STMicroelectronics L7805ACV
GND
VBuck
RBuckon
100
3V3 BUCK
Vin
Vout
+3.3
CigBUCK
10uF
GND
GND
Title Megabit Final Power
Size: A4
Number:4
Revision:1
Date: 21/06/2018
Time: 16:37:16
Sheet4 of 5
File: Power.SchDoc
Imperial College London
CIRCUITMAKER


U555
+3.3
RST
DIS
THR
OUT
TRIG
CVOLT
V+
GND
Op12
LMC555CN
GND
Copt
10uF
GND
R2
Rosl
C555
10uF
GND
f= 1/(1.4RC), datasheet reccomends minimal C and large R
Title Megabit Final Handshake Circuitry
Size: A4
Number:5
Revision:1
Date: 21/06/2018
Time: 16:37:16
Sheet5 of 5
File: Handshake.SchDoc
Imperial College London
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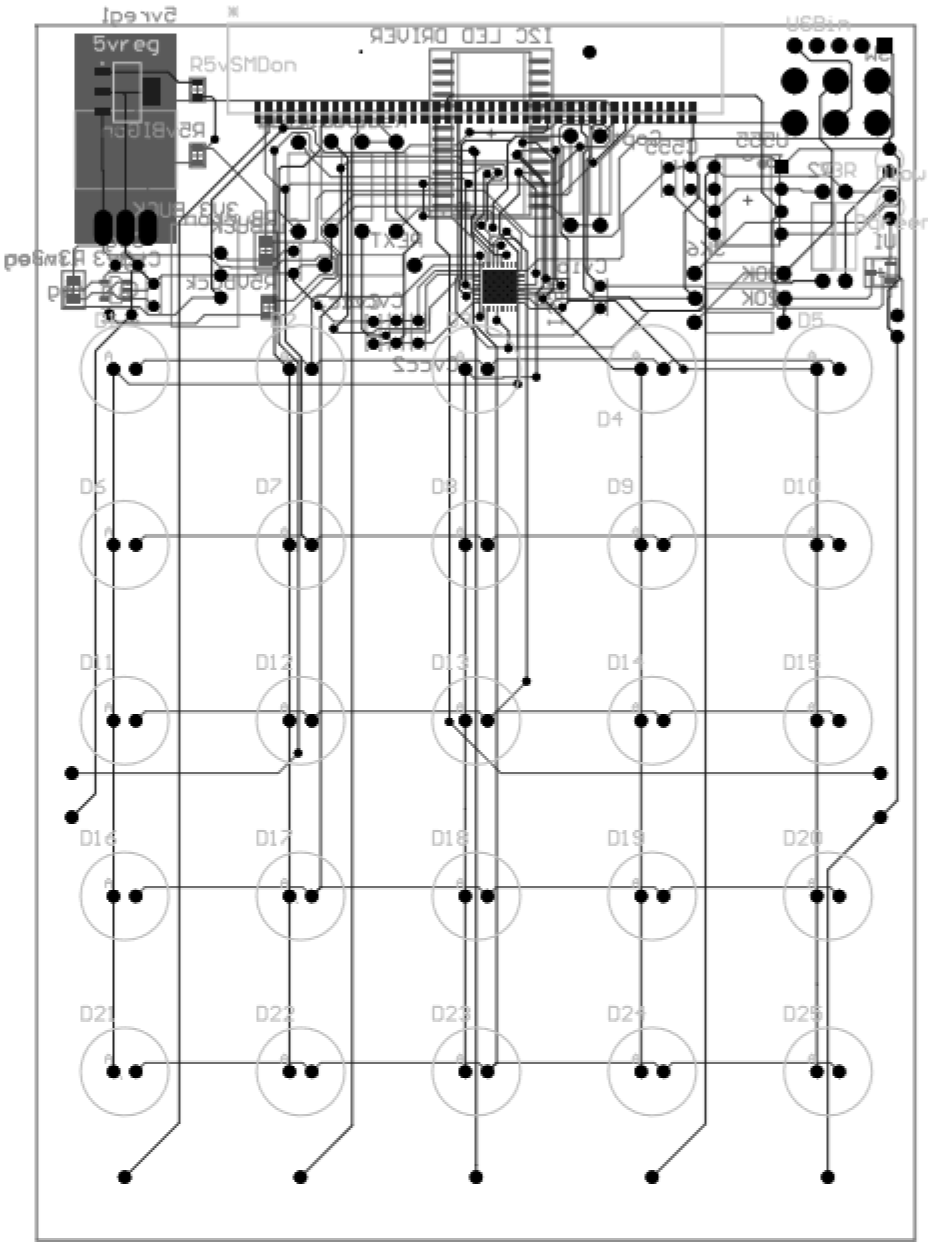

5vreg
R5vSMDon
I2C LED DRIVER
USBin
D5
D4
D6
D7
D8
D9
D10
D11
D12
D13
D14
D15
D16
D17
D18
D19
D20
D21
D22
D23
D24
D25