



# Bitbanging is so 2017

Fast peripheral control from Raspberry Pi  
and friends

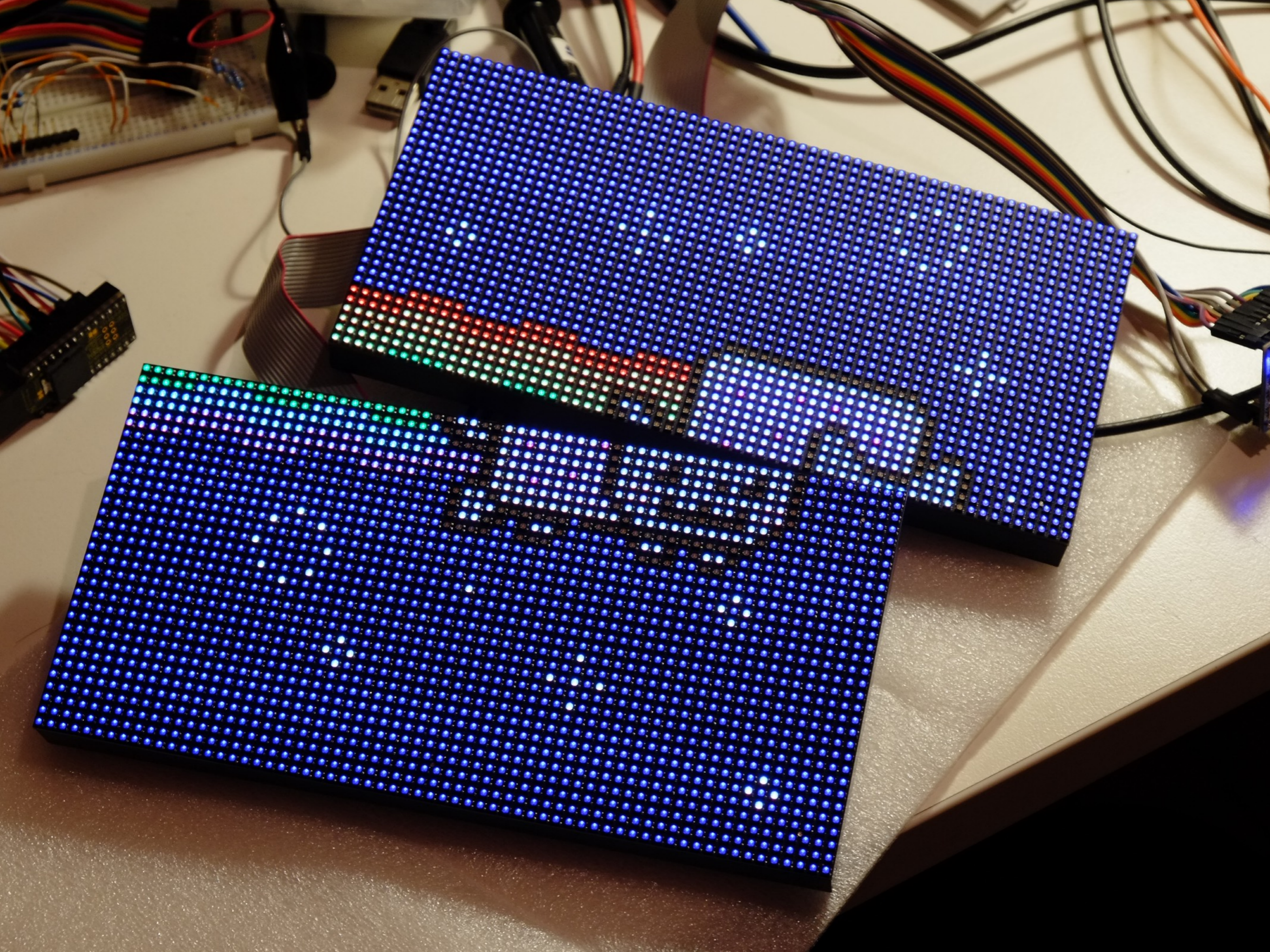
Matt Evans — Hackaday Belgrade 2018

A close-up photograph of a printed circuit board (PCB) populated with a dense grid of surface-mount device (SMD) RGB LEDs. The LEDs are arranged in a regular pattern, and their small, square packages are clearly visible. The lighting is focused, highlighting the individual components and their connections on the board.

# LED panels are amazeballs fun

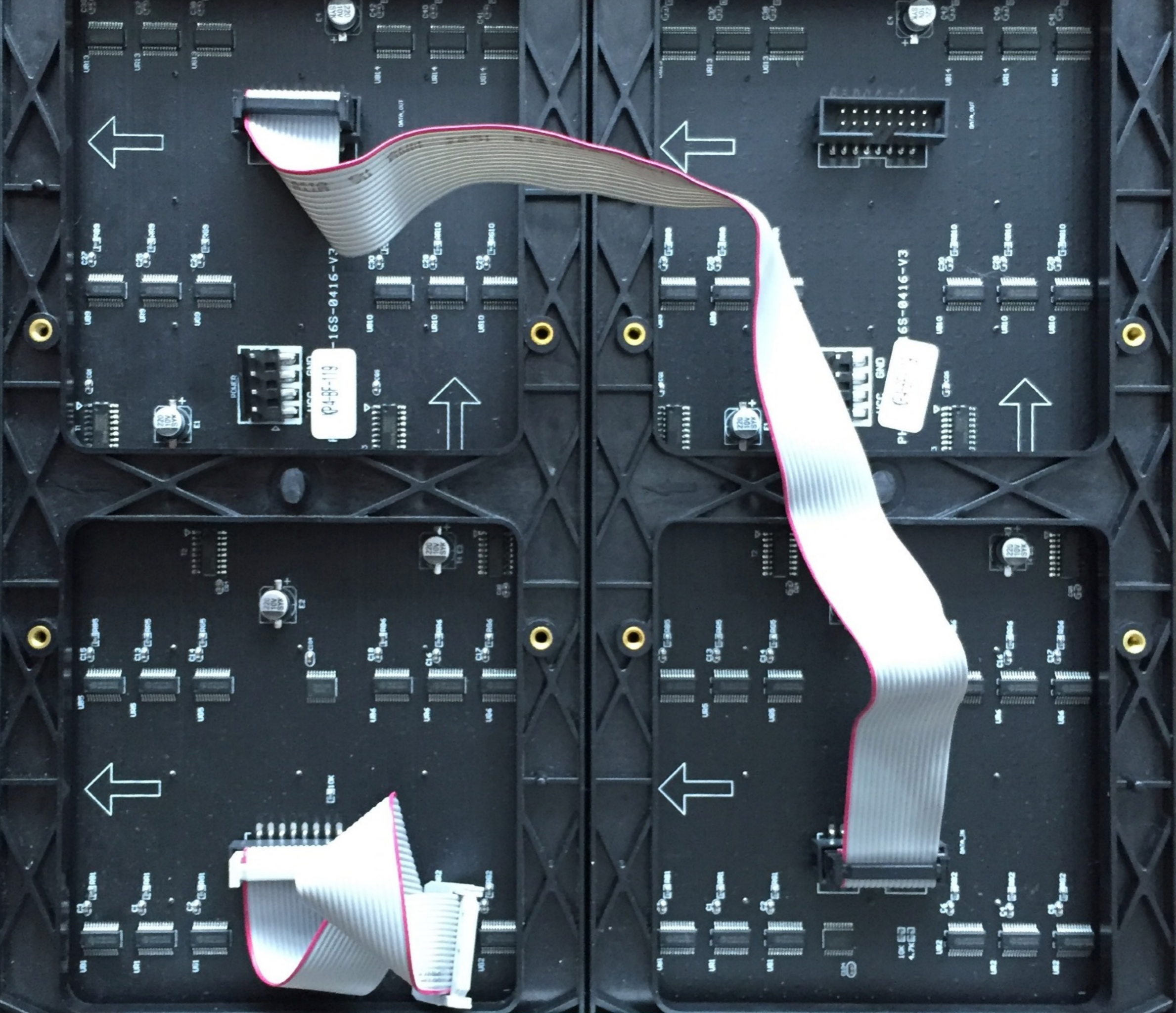
Many SMD RGB LEDs + constant-current driver

Available in many sizes, e.g. 32x16, 32x32, 64x32, 64x64, and pixel pitch

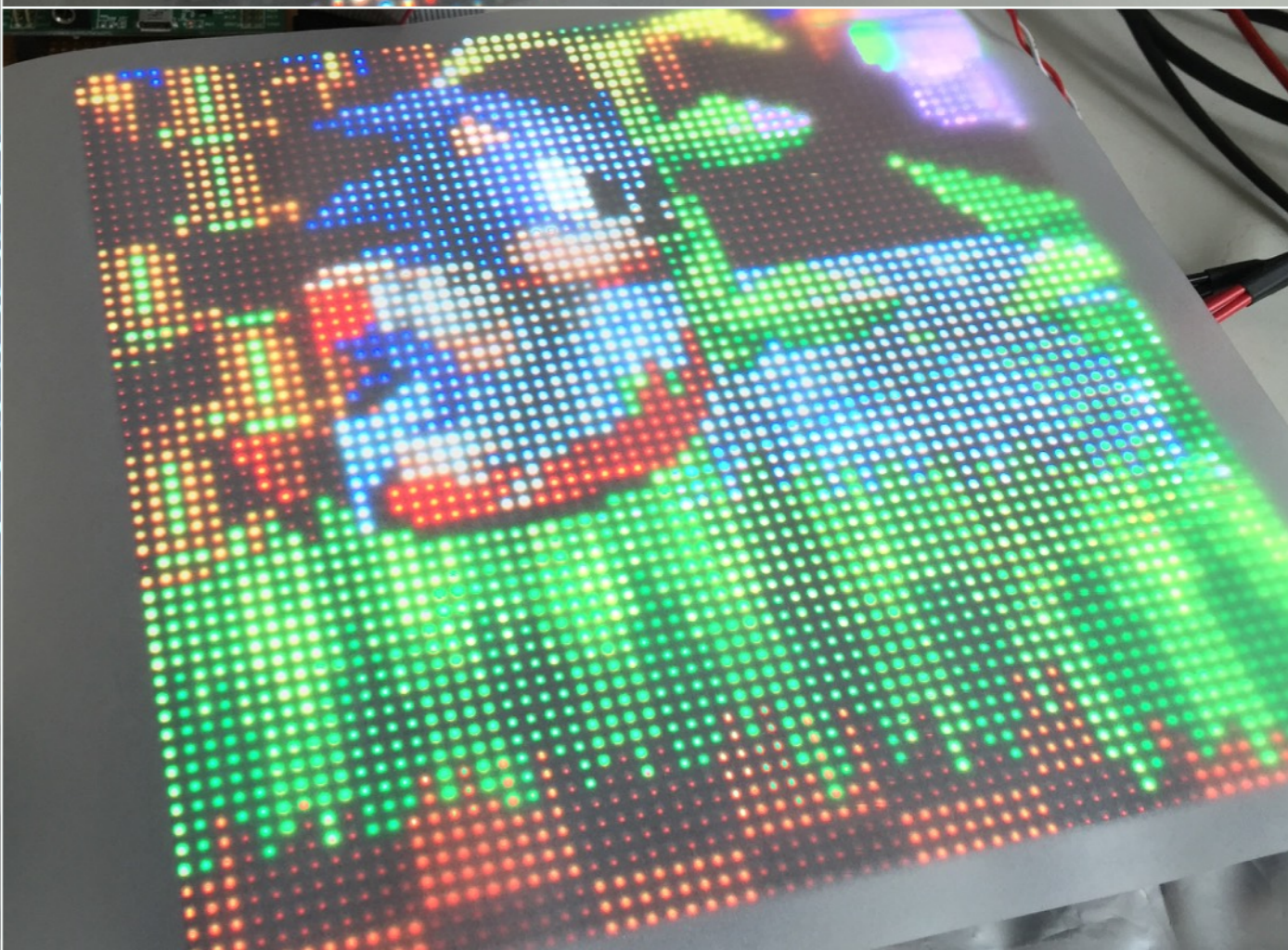
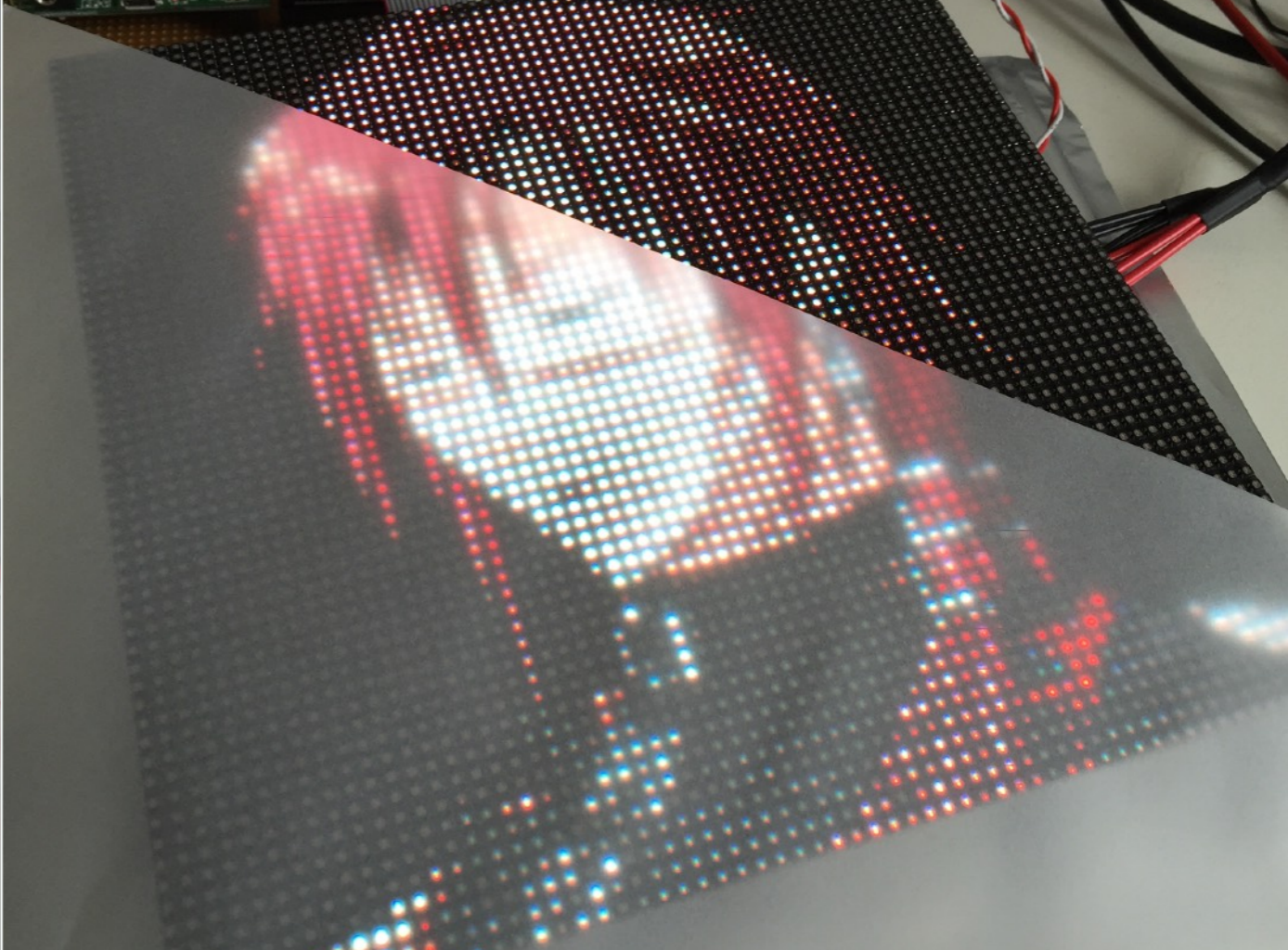
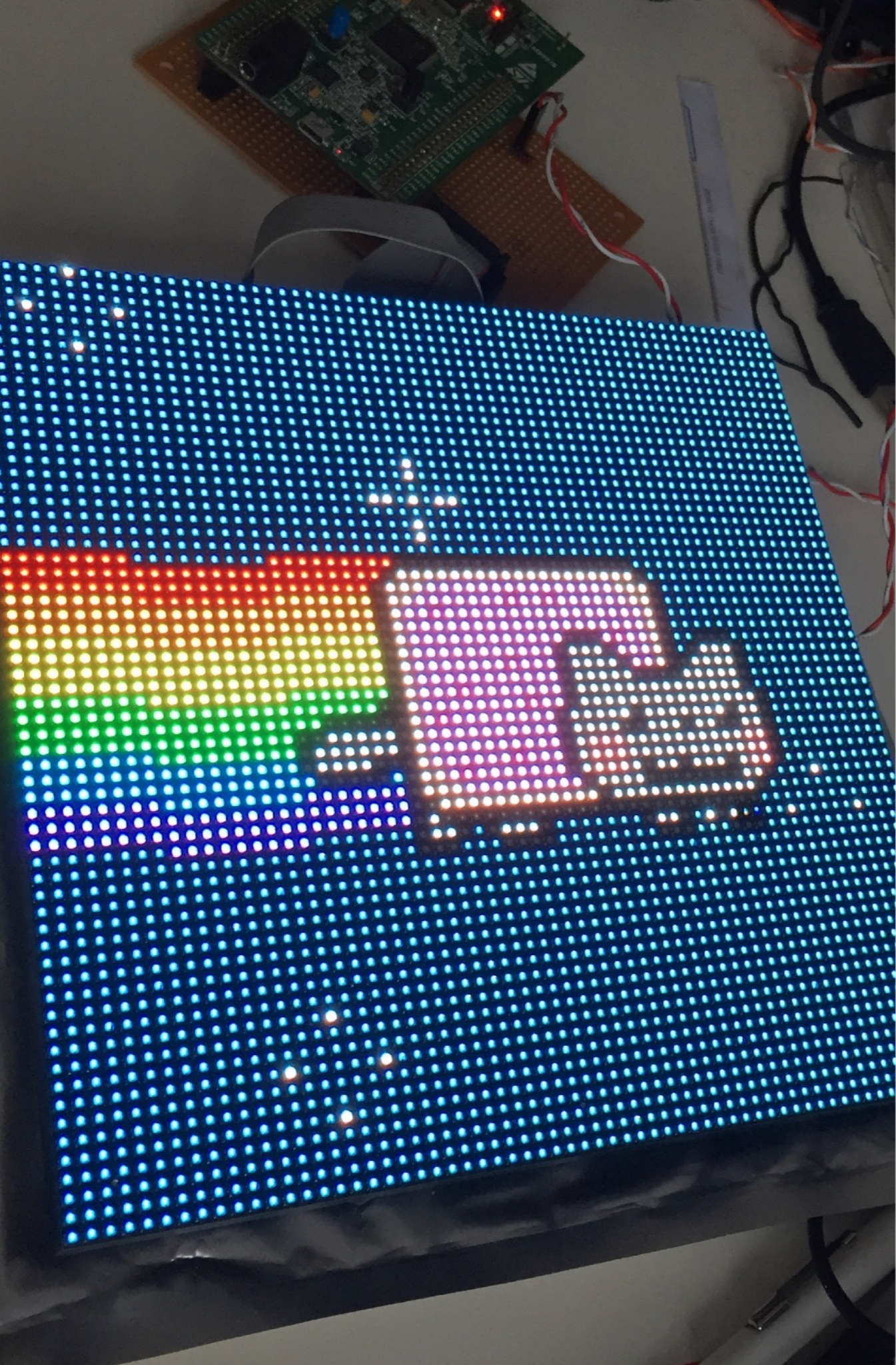




1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24  
STAINLESS STEEL







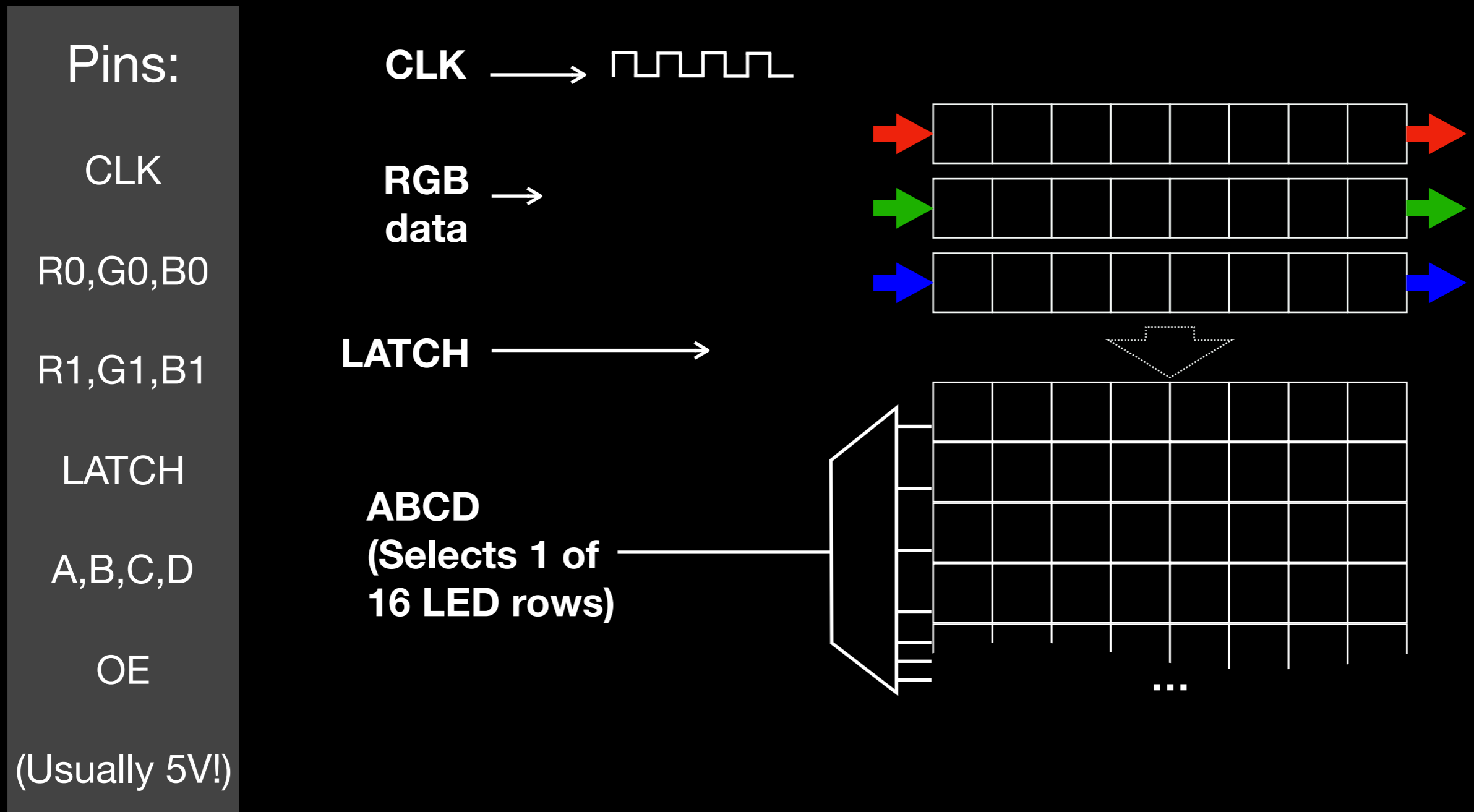
# LED panels from a Raspberry Pi

- Great library for driving LED panels from Raspberry Pi:
  - <https://github.com/hzeller/rpi-rgb-led-matrix>
- But, doesn't use DMA — *it bitbangs, software loop*
- "The system needs constant CPU ... roughly 30-40% of one core."
- To avoid flicker: "If you have a loaded system ... you can **reserve one core** just for the refresh of the display" 😞



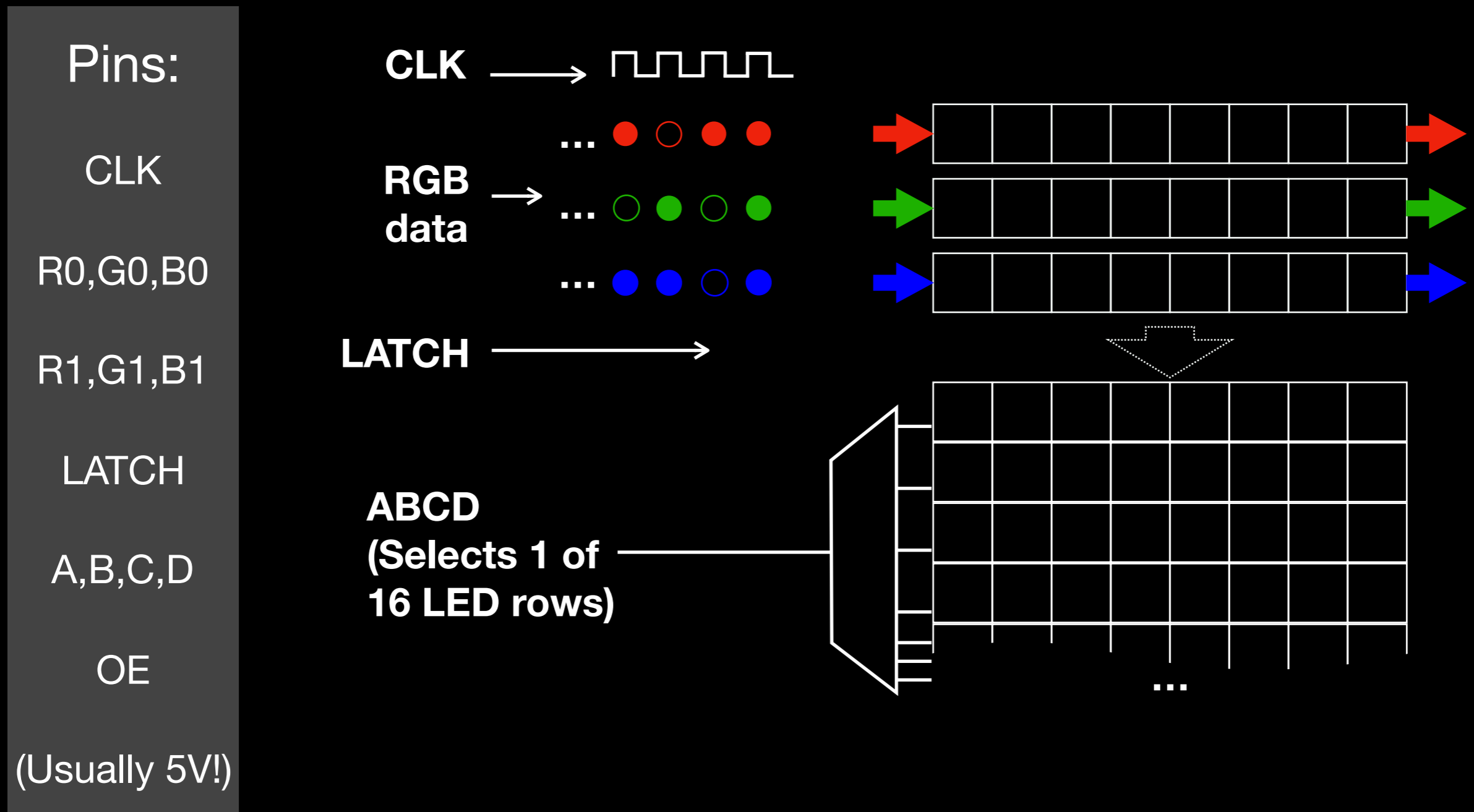
# HUB75 panel interface

(it's all a big shift register)



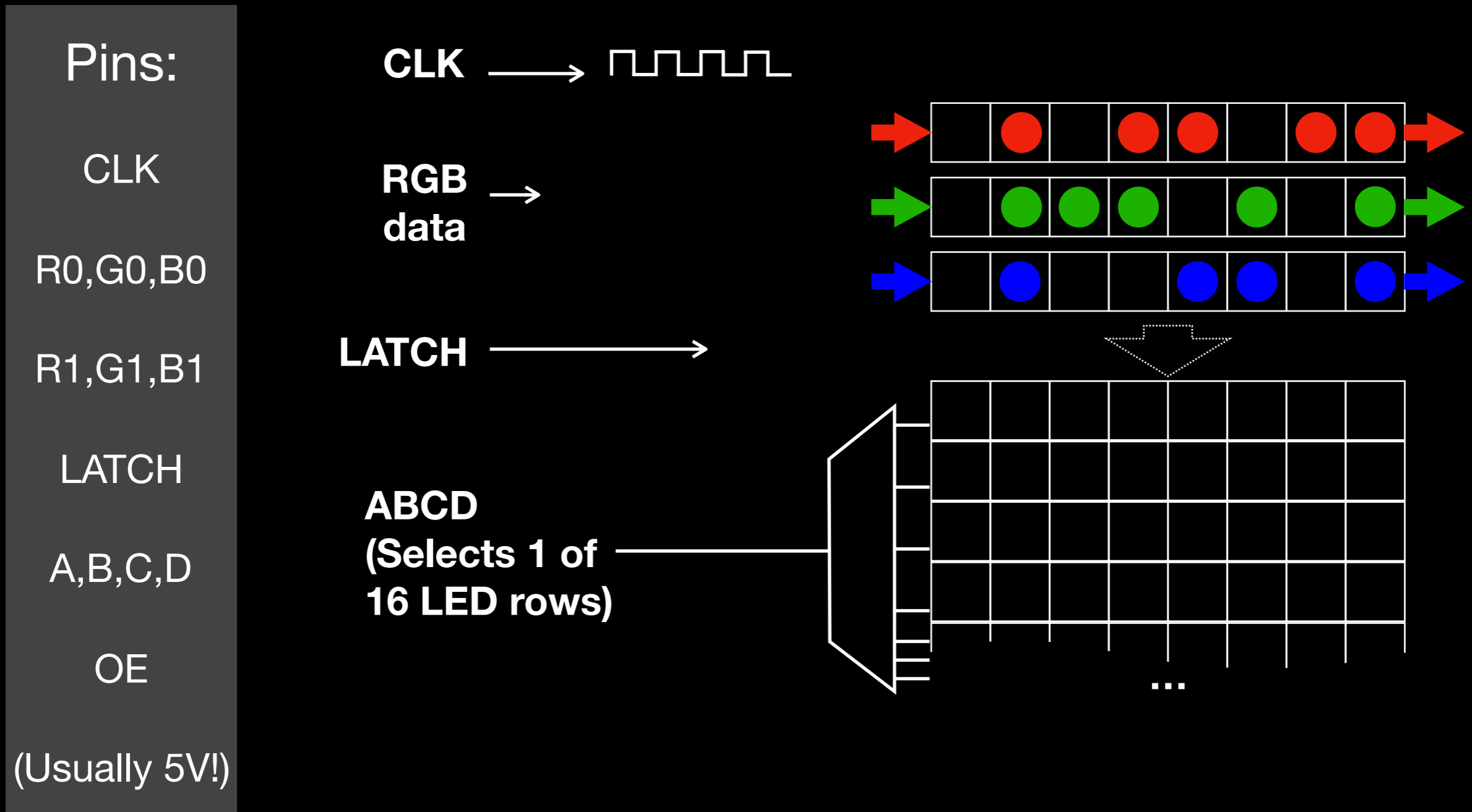
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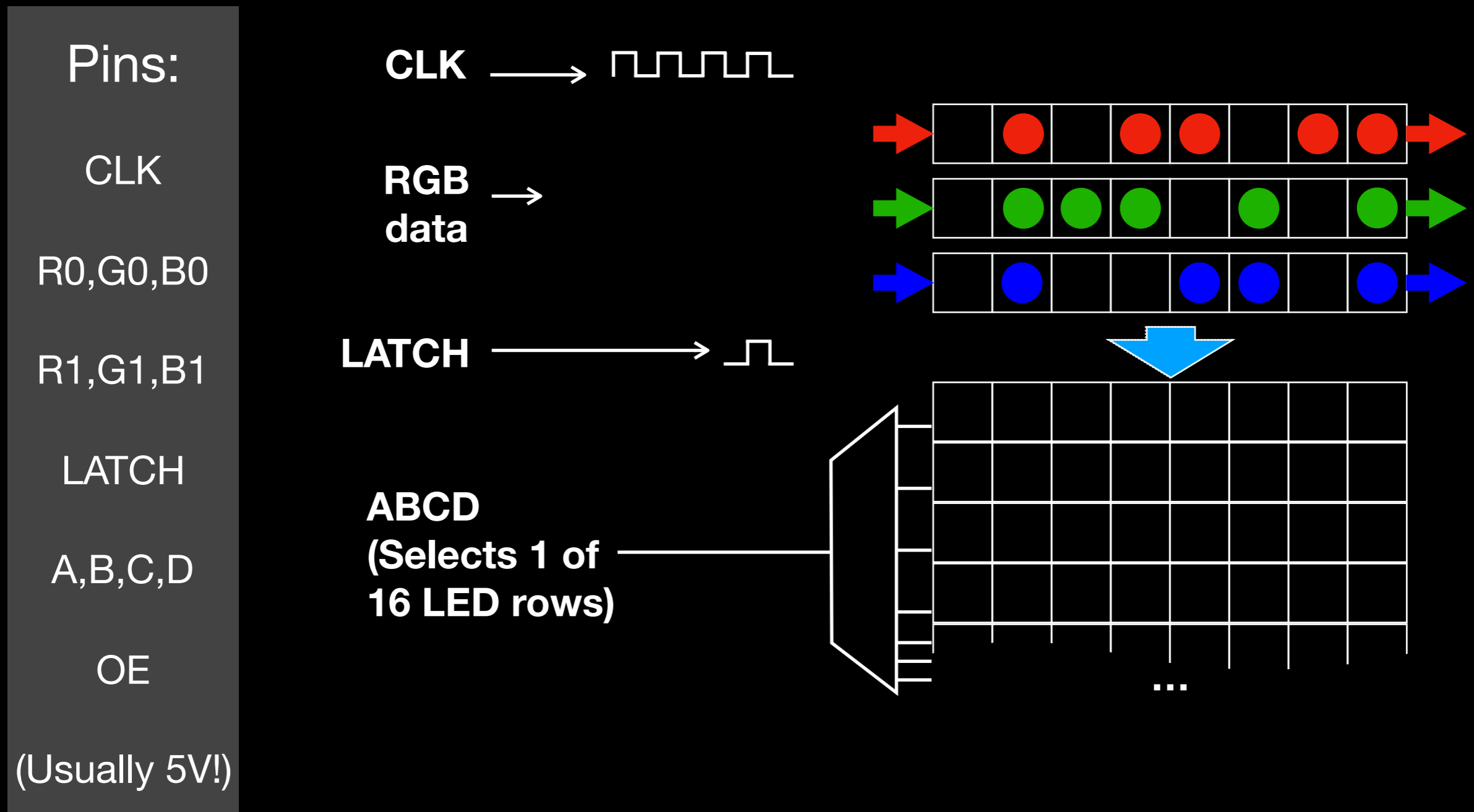
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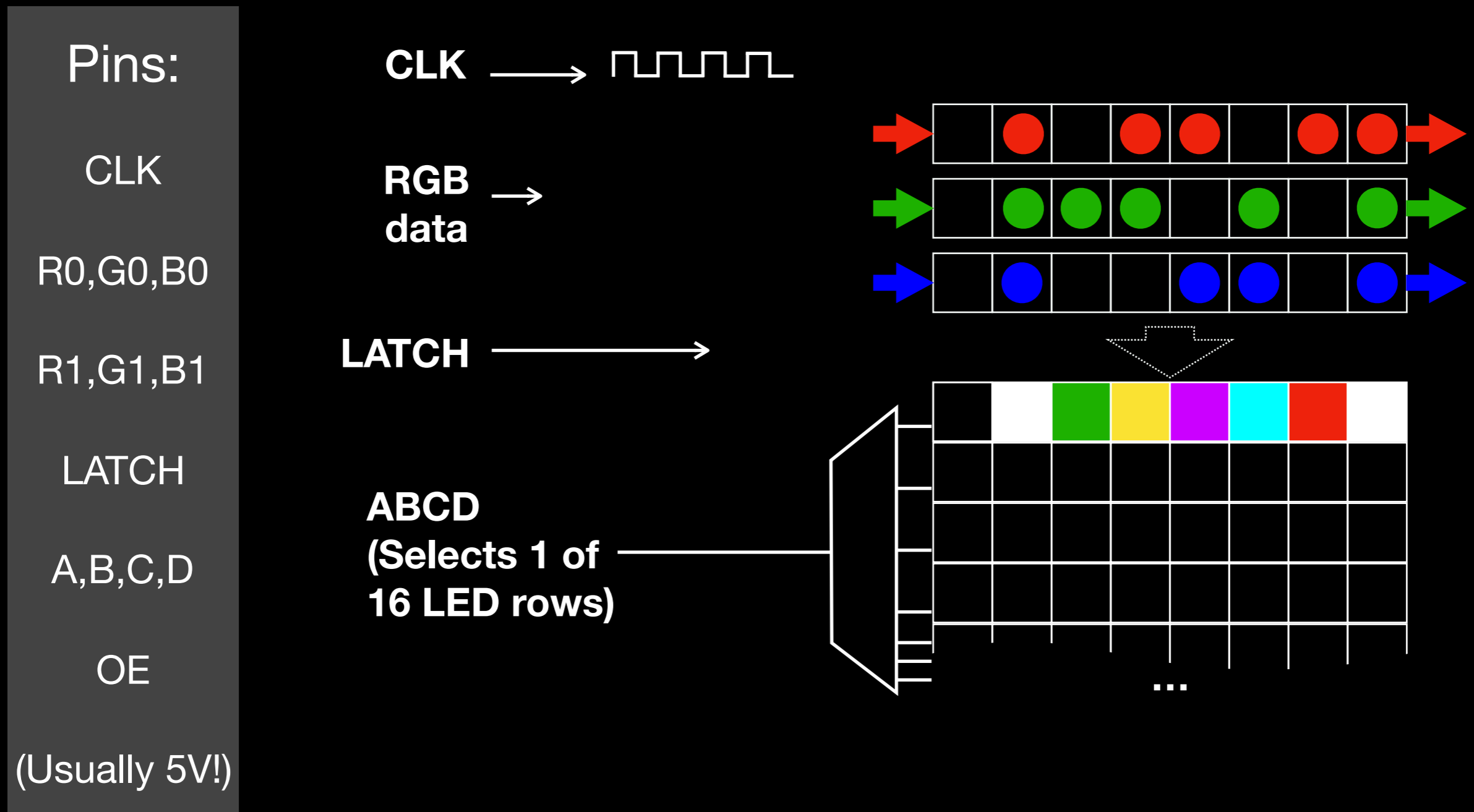
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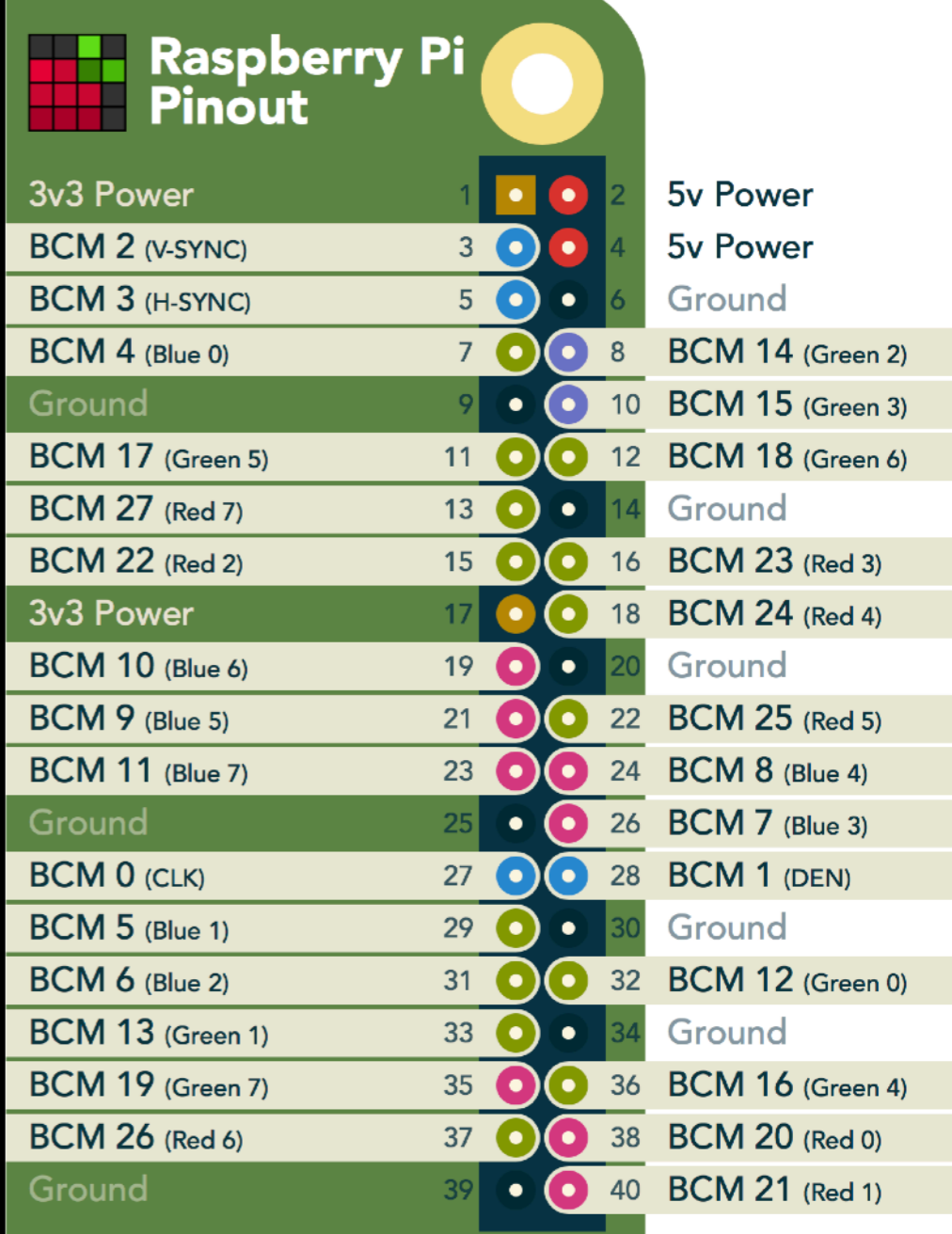
# HUB75 panel interface

(it's all a big shift register)



# Display Parallel Interface (DPI)

- Once upon a time, I was attaching an LCD to a RPi using DPI
- Parallel interface designed to drive TFT LCDs from BCM2835 — alternative to HDMI
- 24-bit pixel output (+ pixel clock, + sync bits) high-speed digital output, 3.3V CMOS



**Raspberry Pi Pinout**

3v3 Power	1	2	5v Power
BCM 2 (V-SYNC)	3	4	5v Power
BCM 3 (H-SYNC)	5	6	Ground
BCM 4 (Blue 0)	7	8	BCM 14 (Green 2)
Ground	9	10	BCM 15 (Green 3)
BCM 17 (Green 5)	11	12	BCM 18 (Green 6)
BCM 27 (Red 7)	13	14	Ground
BCM 22 (Red 2)	15	16	BCM 23 (Red 3)
3v3 Power	17	18	BCM 24 (Red 4)
BCM 10 (Blue 6)	19	20	Ground
BCM 9 (Blue 5)	21	22	BCM 25 (Red 5)
BCM 11 (Blue 7)	23	24	BCM 8 (Blue 4)
Ground	25	26	BCM 7 (Blue 3)
BCM 0 (CLK)	27	28	BCM 1 (DEN)
BCM 5 (Blue 1)	29	30	Ground
BCM 6 (Blue 2)	31	32	BCM 12 (Green 0)
BCM 13 (Green 1)	33	34	Ground
BCM 19 (Green 7)	35	36	BCM 16 (Green 4)
BCM 26 (Red 6)	37	38	BCM 20 (Red 0)
Ground	39	40	BCM 21 (Red 1)

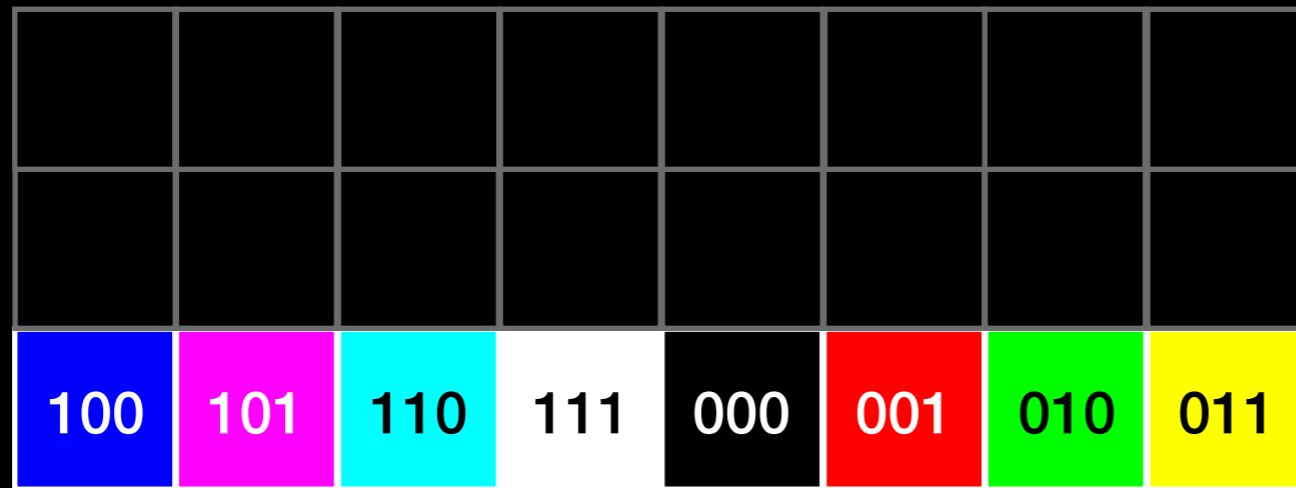
# I haz an idea!

Put *pixel patterns* in the video framebuffer that send digital *data patterns* to DPI output pins!

No CPU overhead to display it

Guaranteed not to hiccup

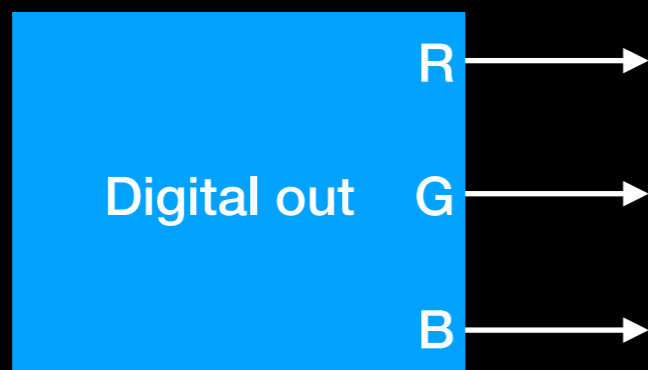
# Parallel video out



One line of framebuffer

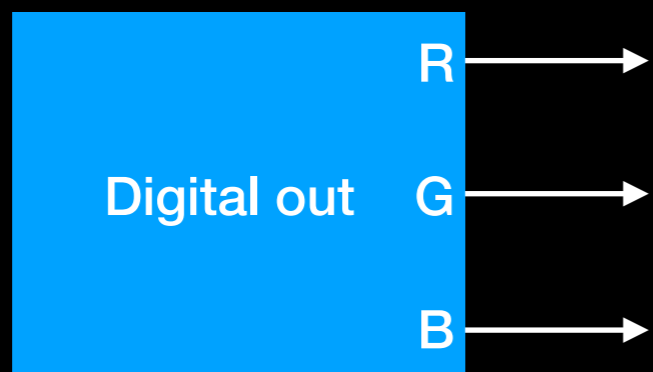
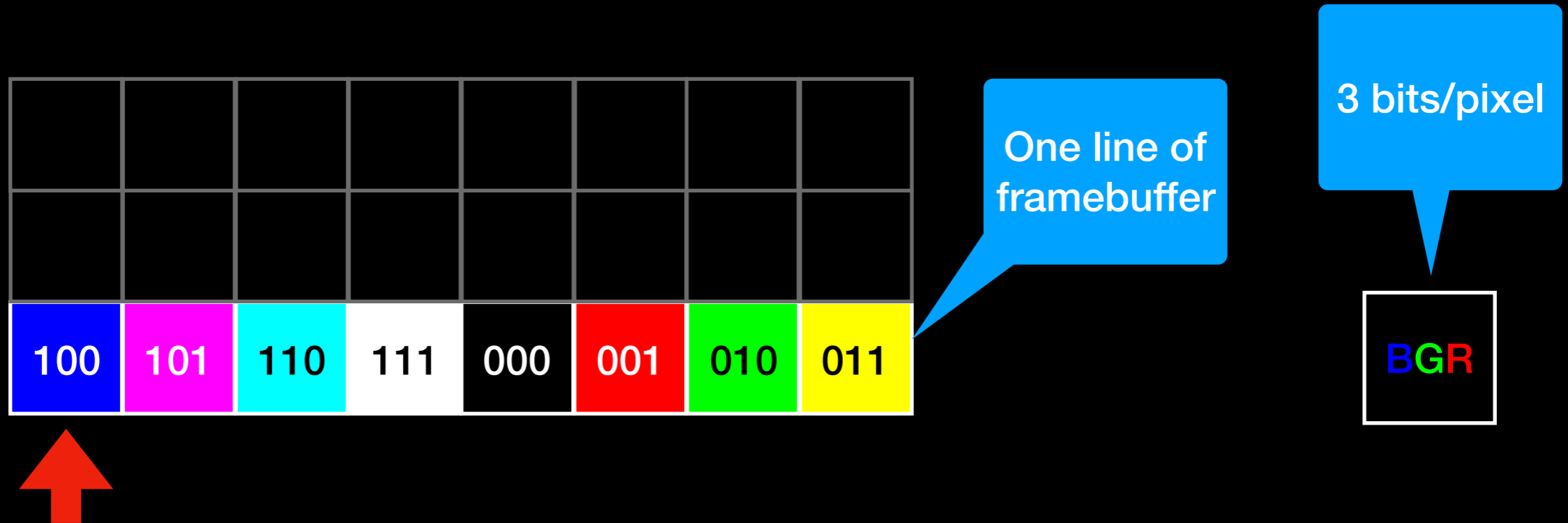
3 bits/pixel

BGR

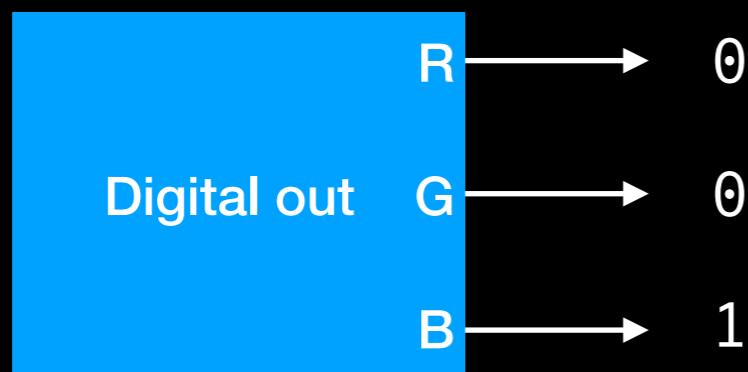
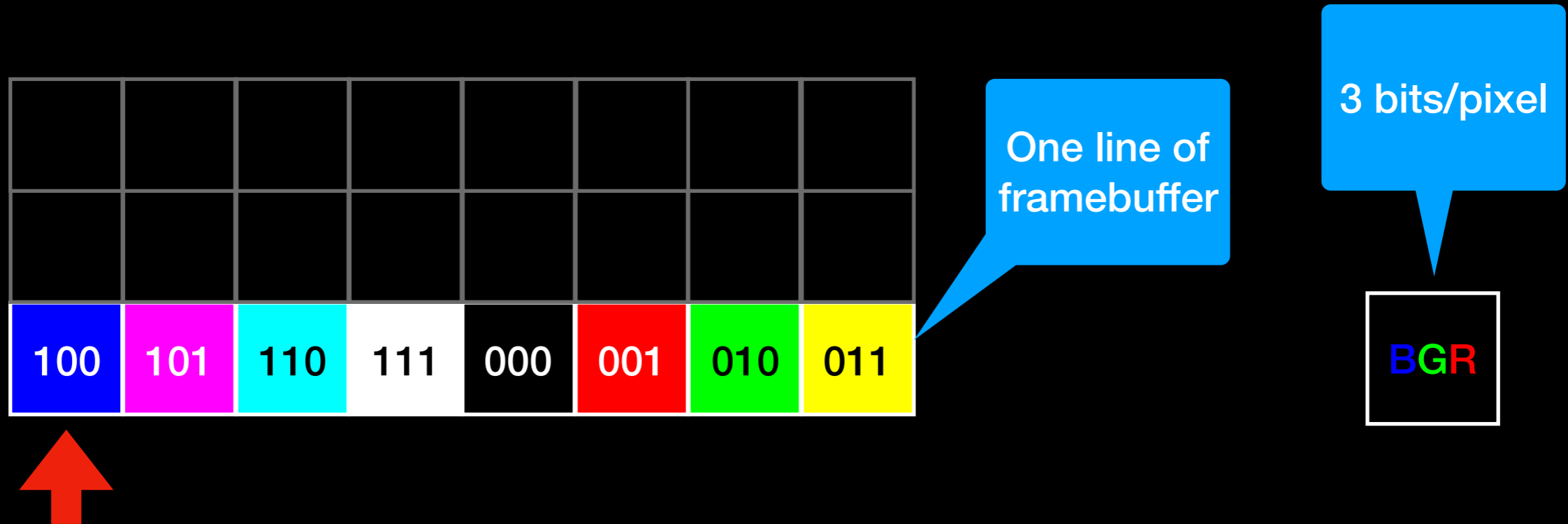




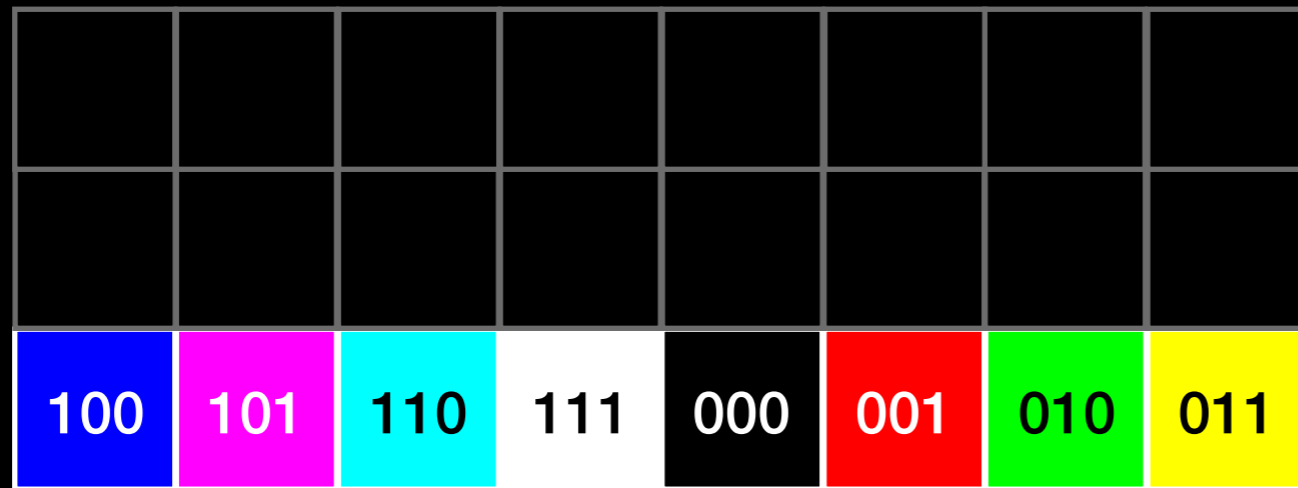
# Parallel video out



# Parallel video out



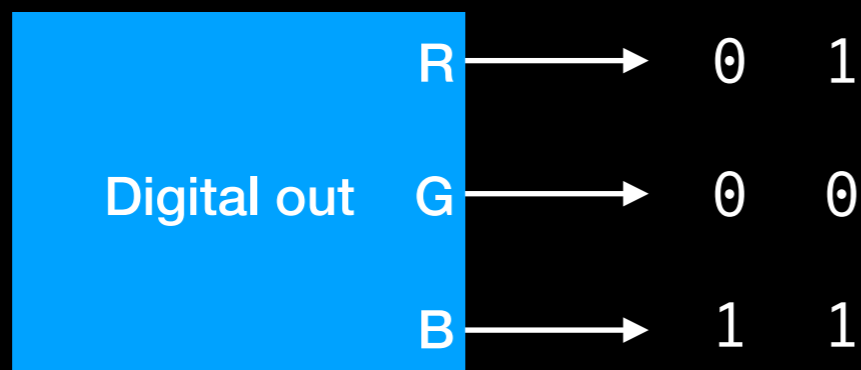
# Parallel video out



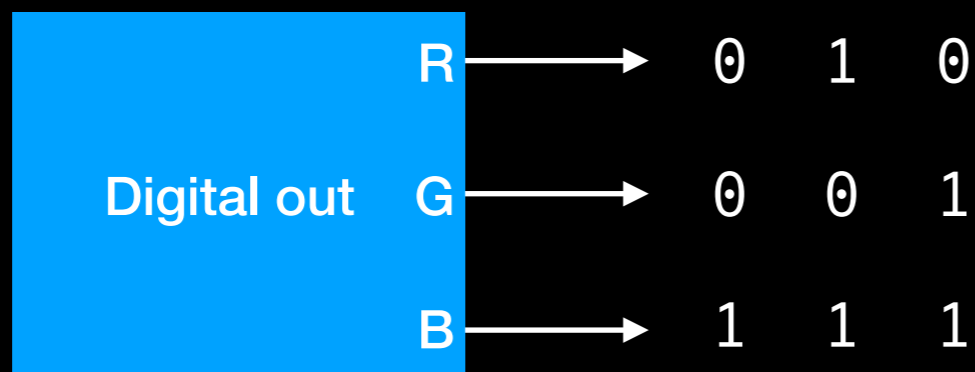
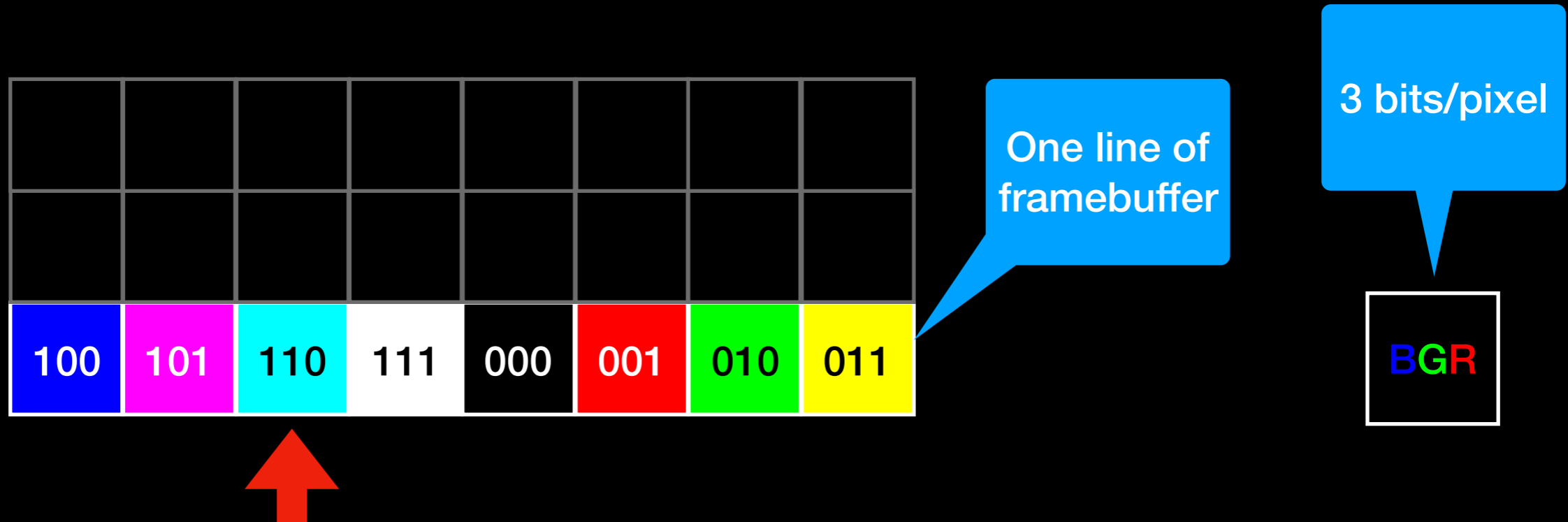
One line of framebuffer

3 bits/pixel

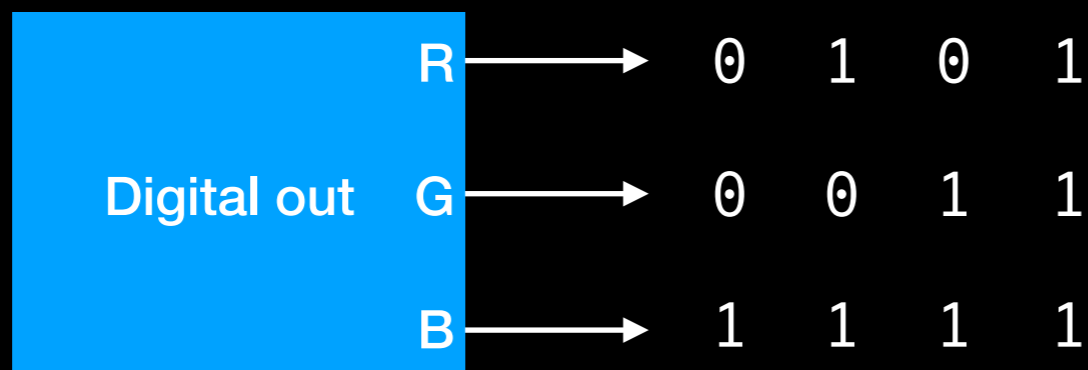
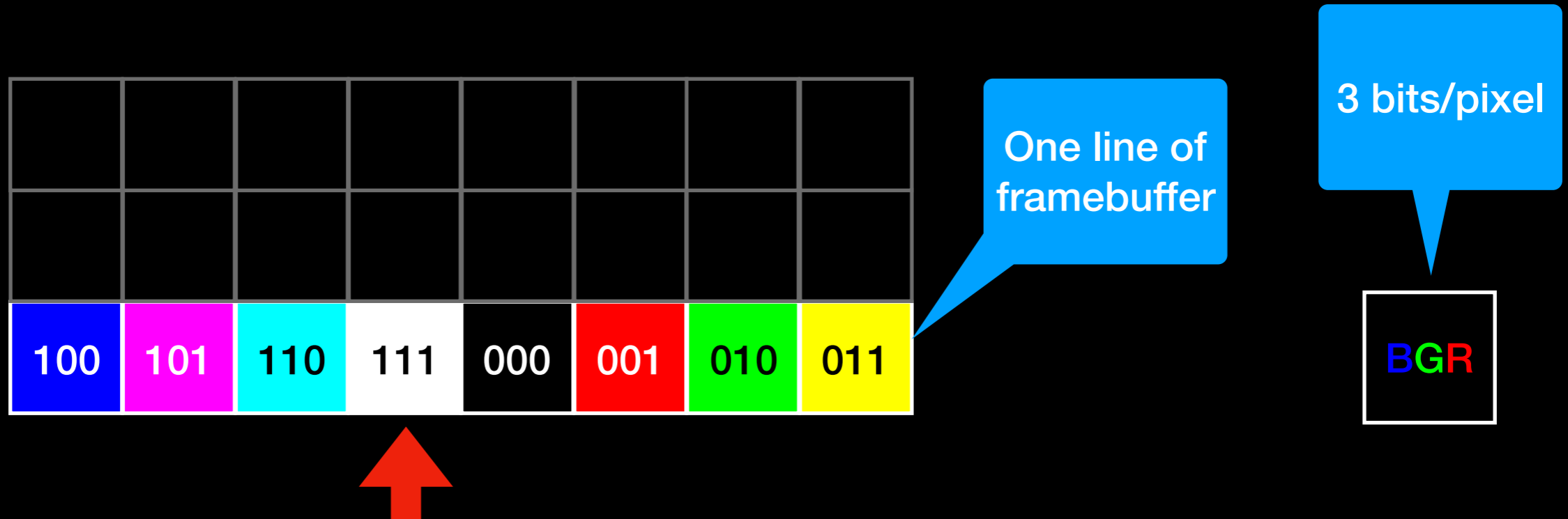
BGR



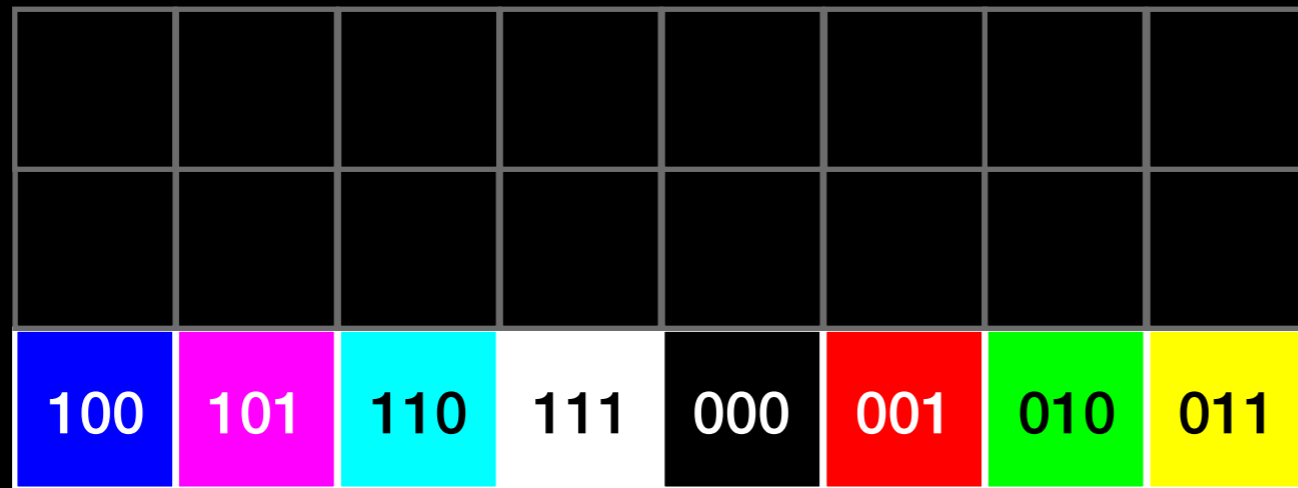
# Parallel video out



# Parallel video out



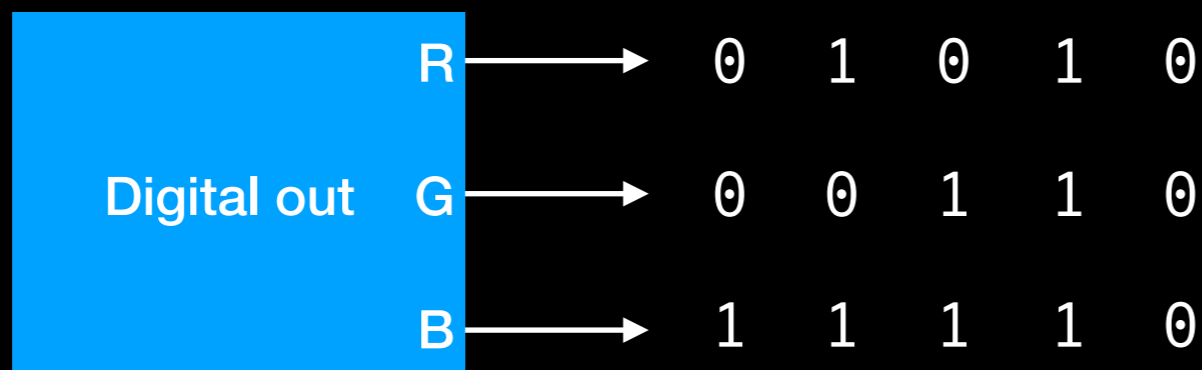
# Parallel video out



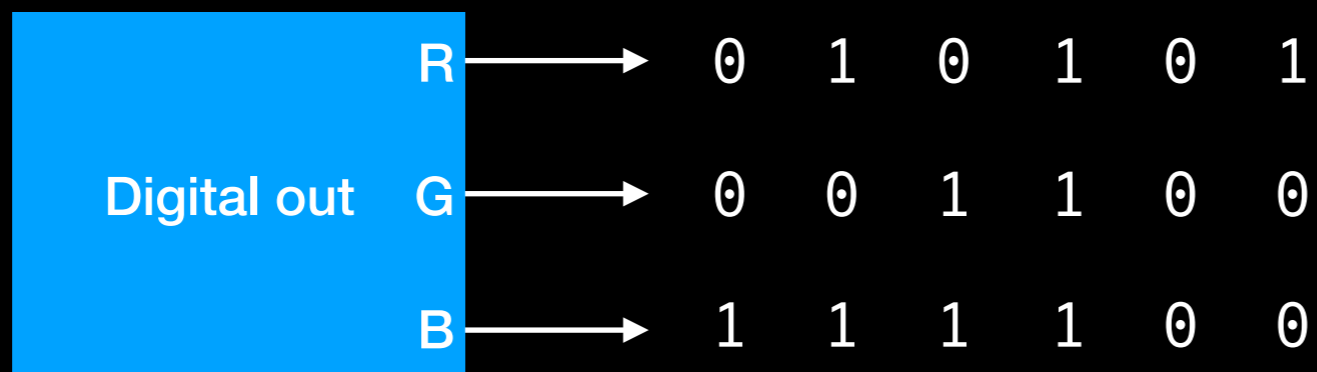
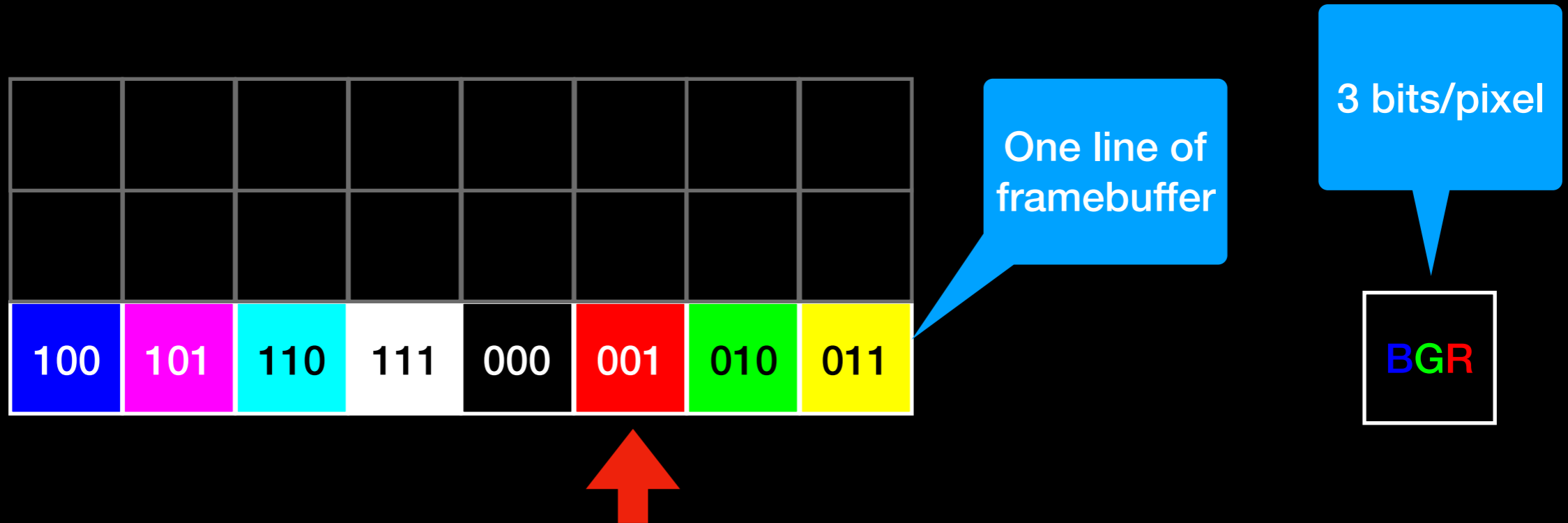
One line of framebuffer

3 bits/pixel

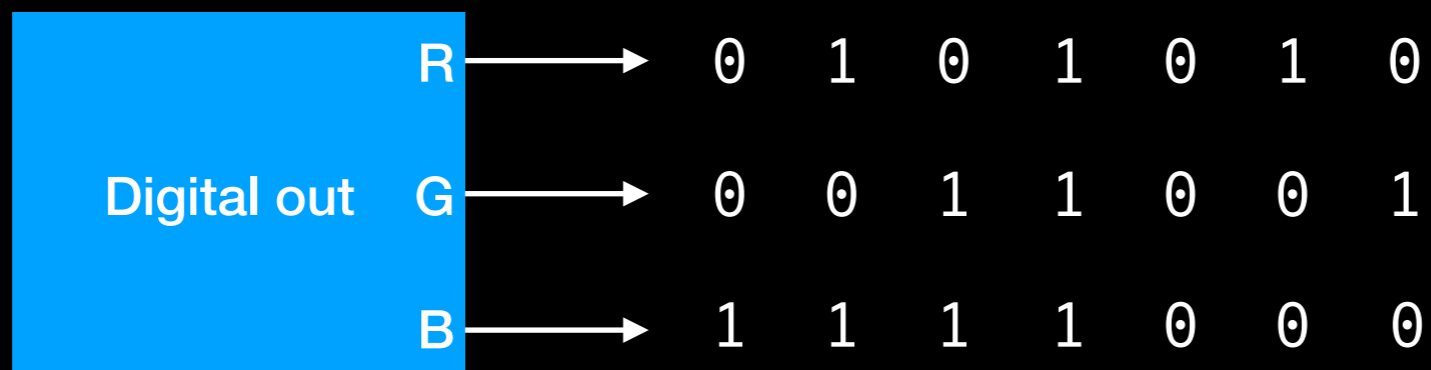
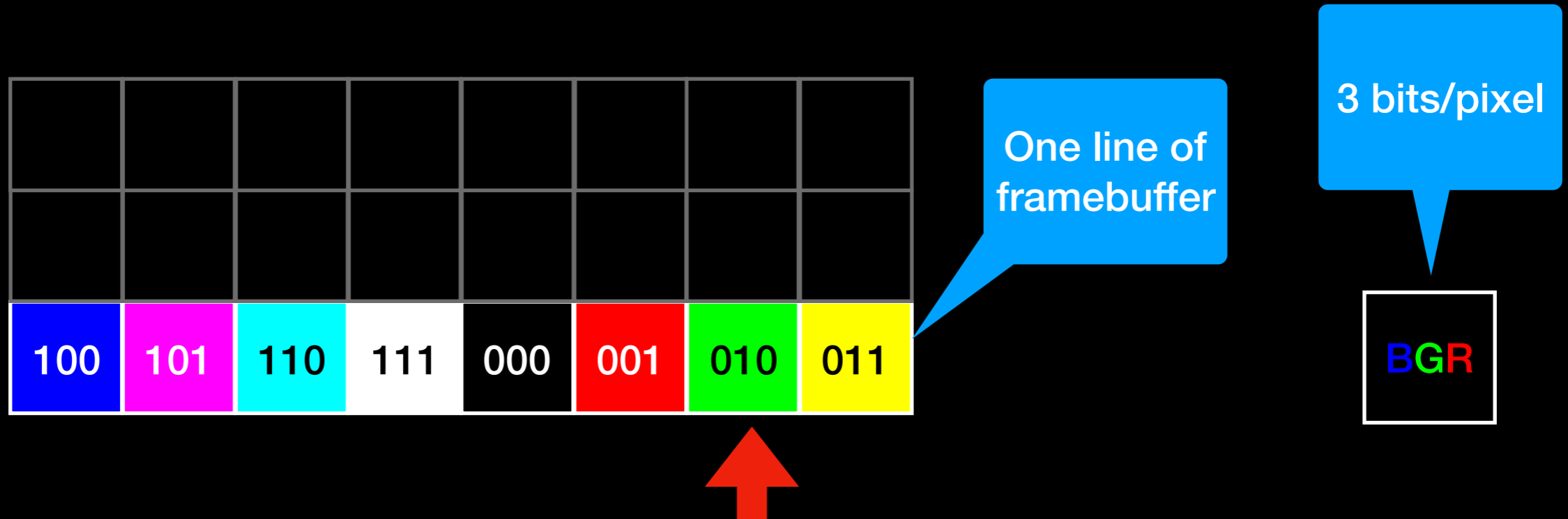
BGR



# Parallel video out

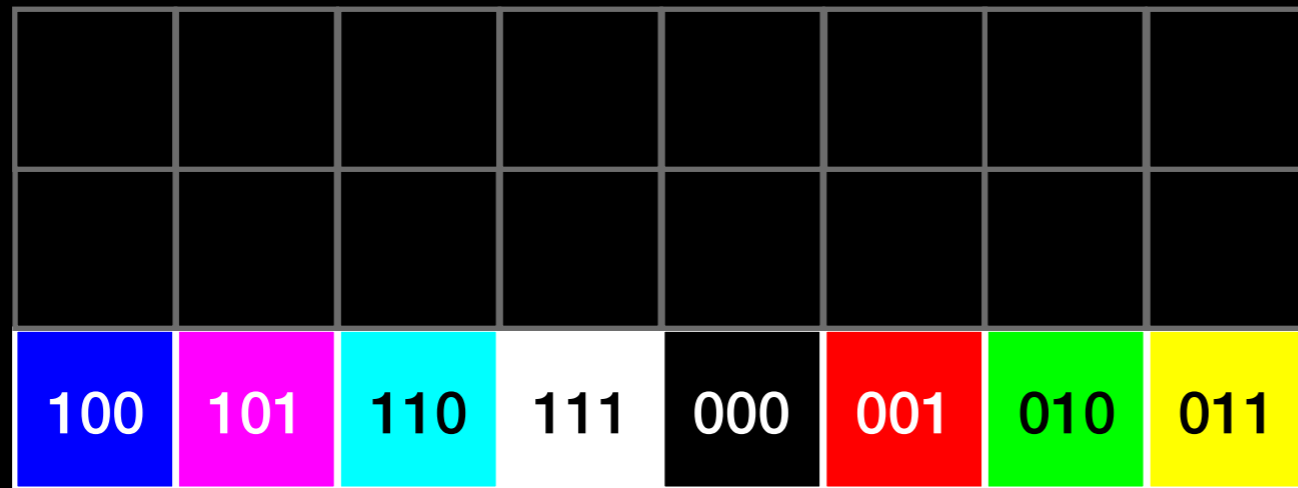


# Parallel video out





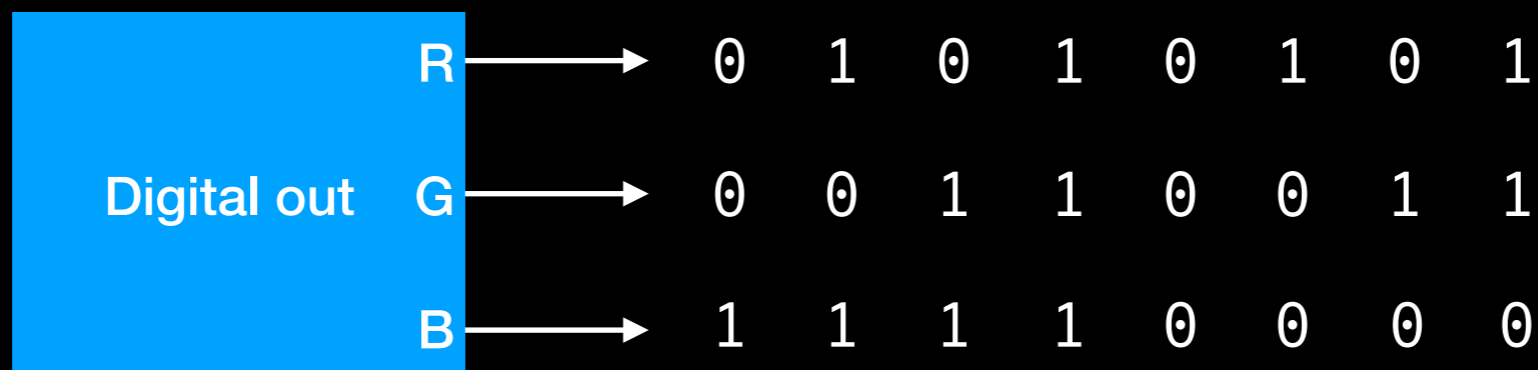
# Parallel video out



One line of framebuffer

3 bits/pixel

BGR



# Misusing video outputs

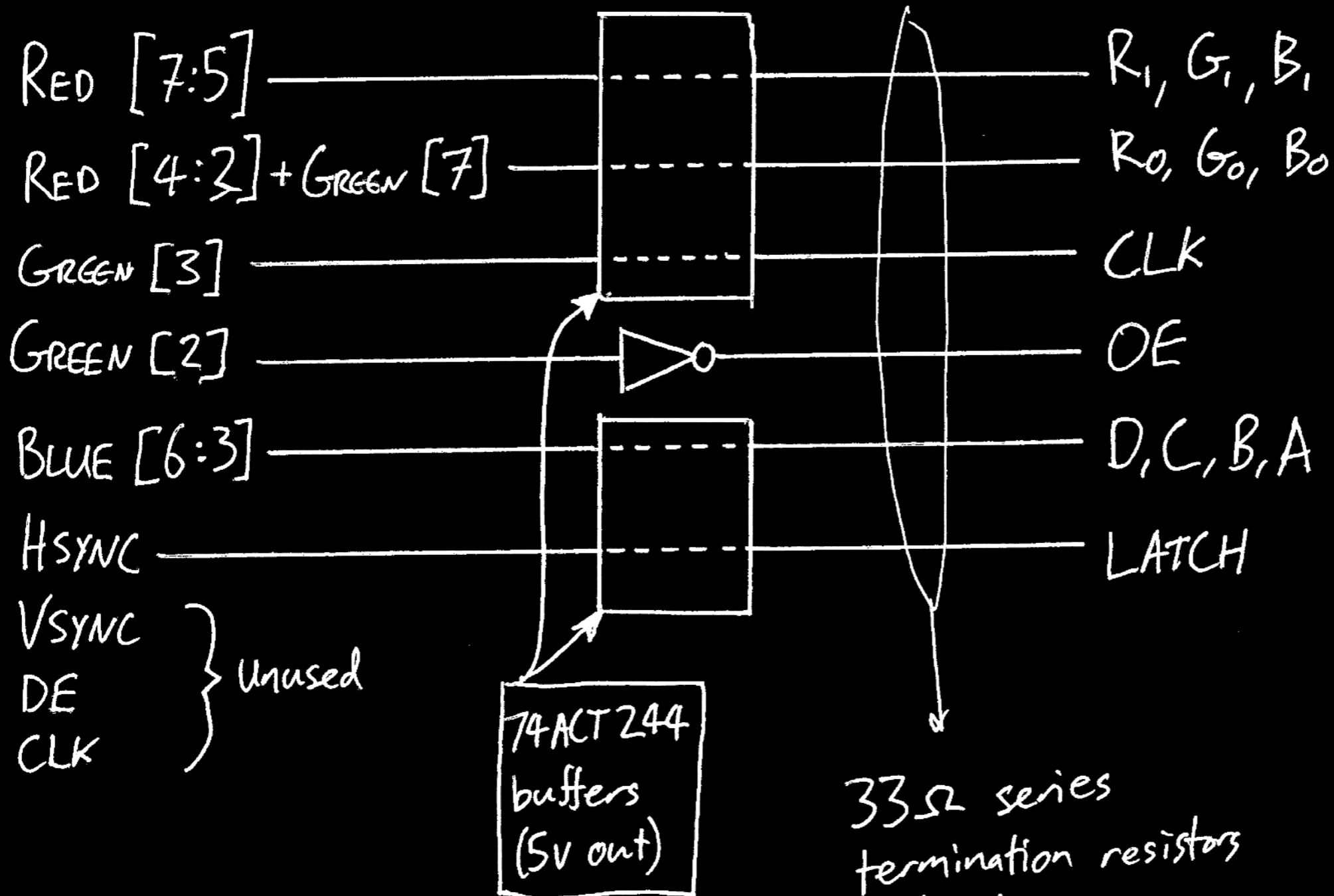
- You may have seen people using VGA for analog out:
  - Tempest for Eliza: AM radio transmitter
  - Fabrice Bellard's DVB-T transmitter
  - osmo-fl2k: Using FL2000 USB dongle as SDR transmitter
- Haven't found any projects using *digital* video out for other things

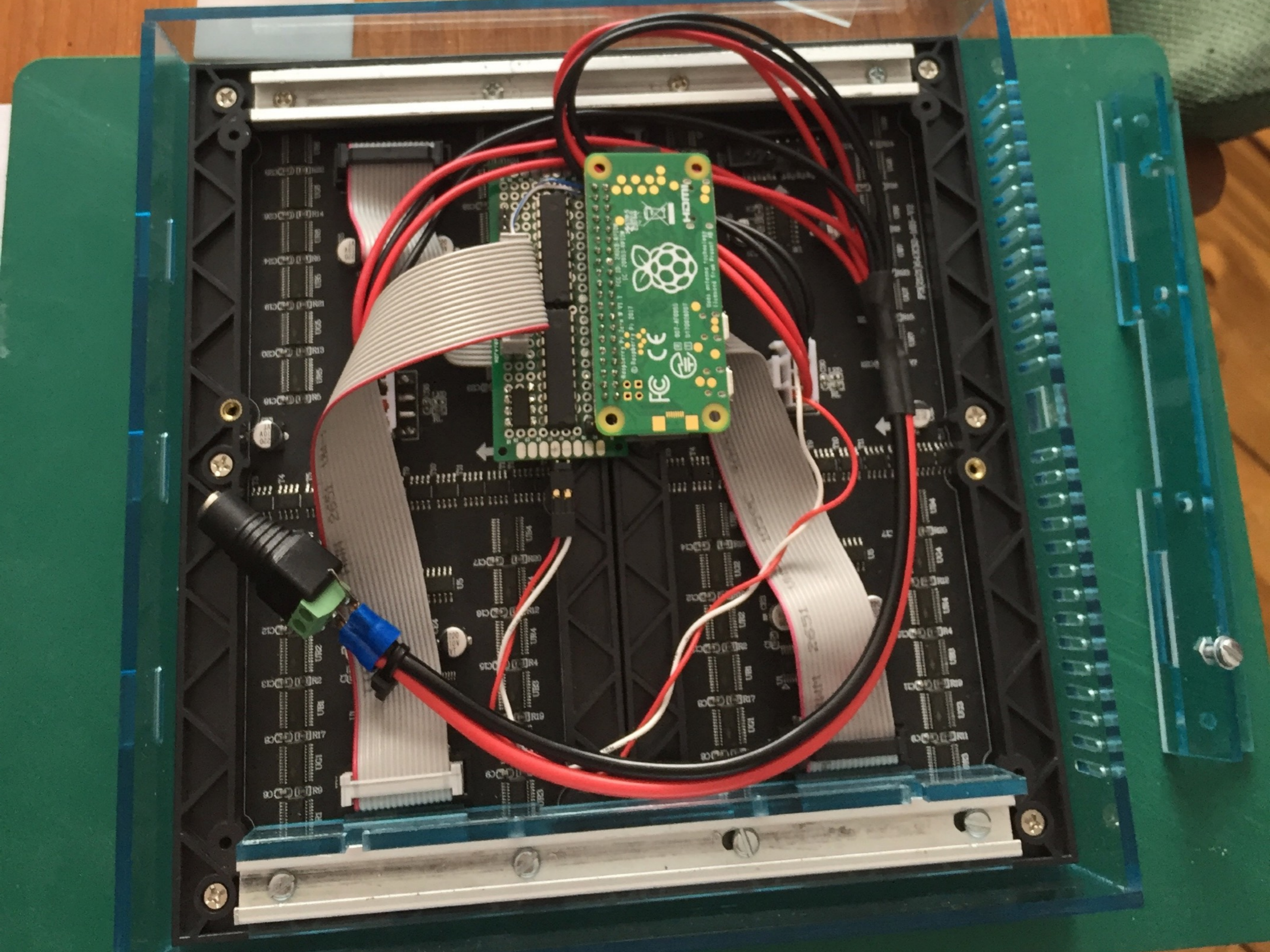


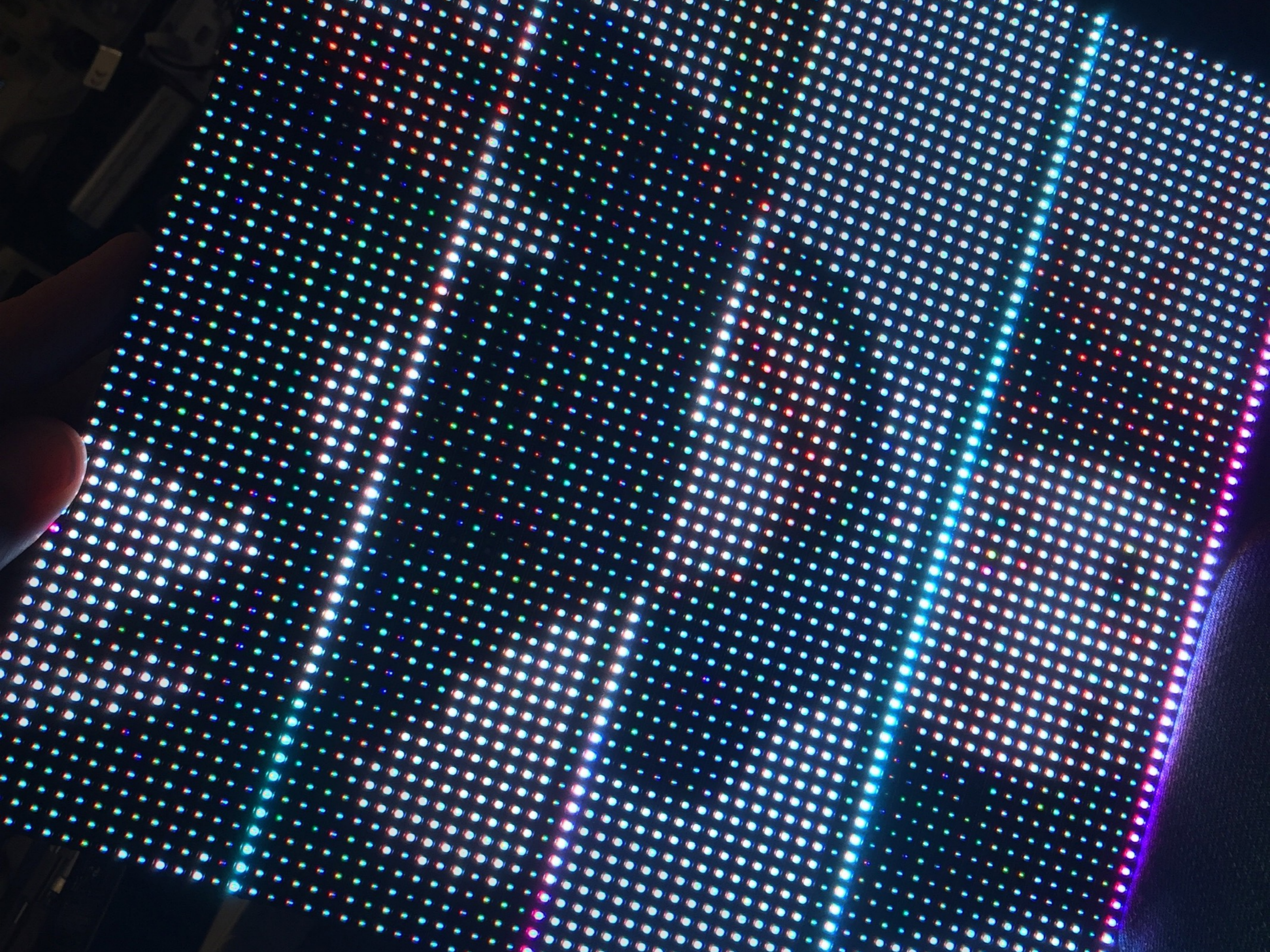
# Wiring HUB75 to DPI

RPi DPI pins (3.3v)

HUB75 pins (5v)





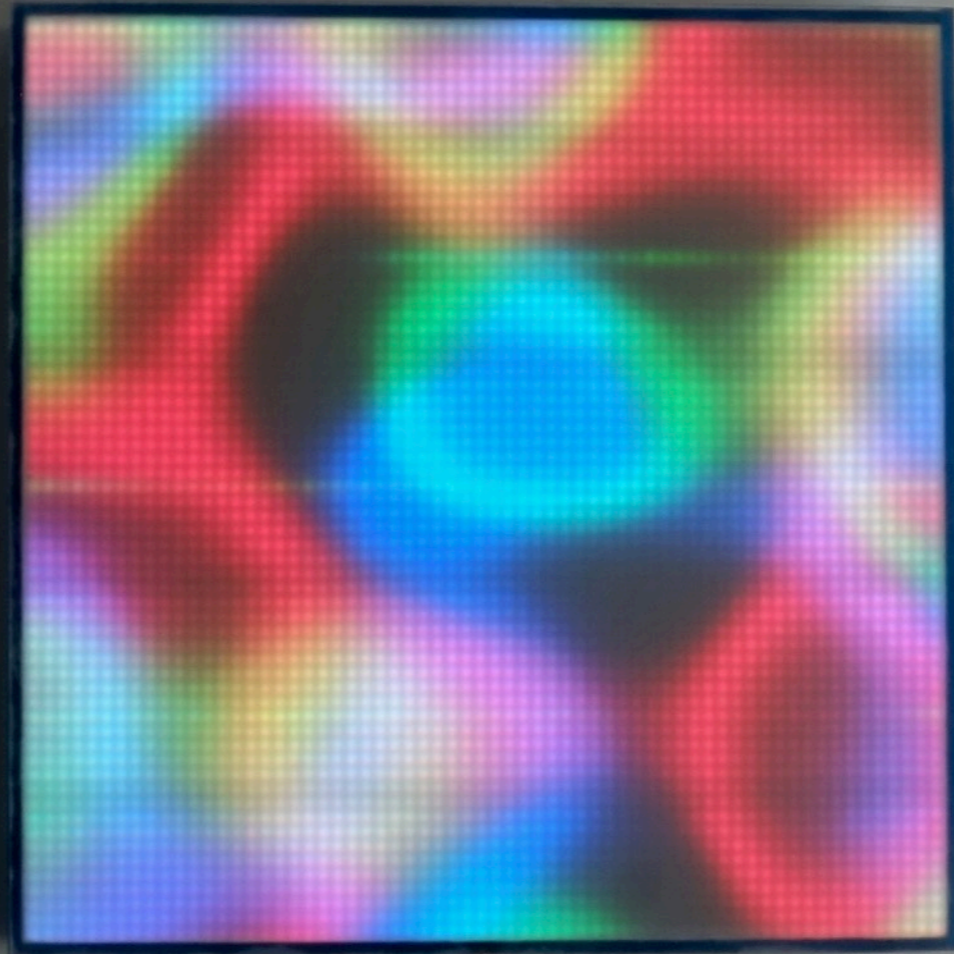


1. **Introduction**  
This report discusses the importance of maintaining accurate records in a business environment. It covers the various methods used for record-keeping and the benefits of a well-organized system. The document is structured into several sections, each focusing on a different aspect of record management.

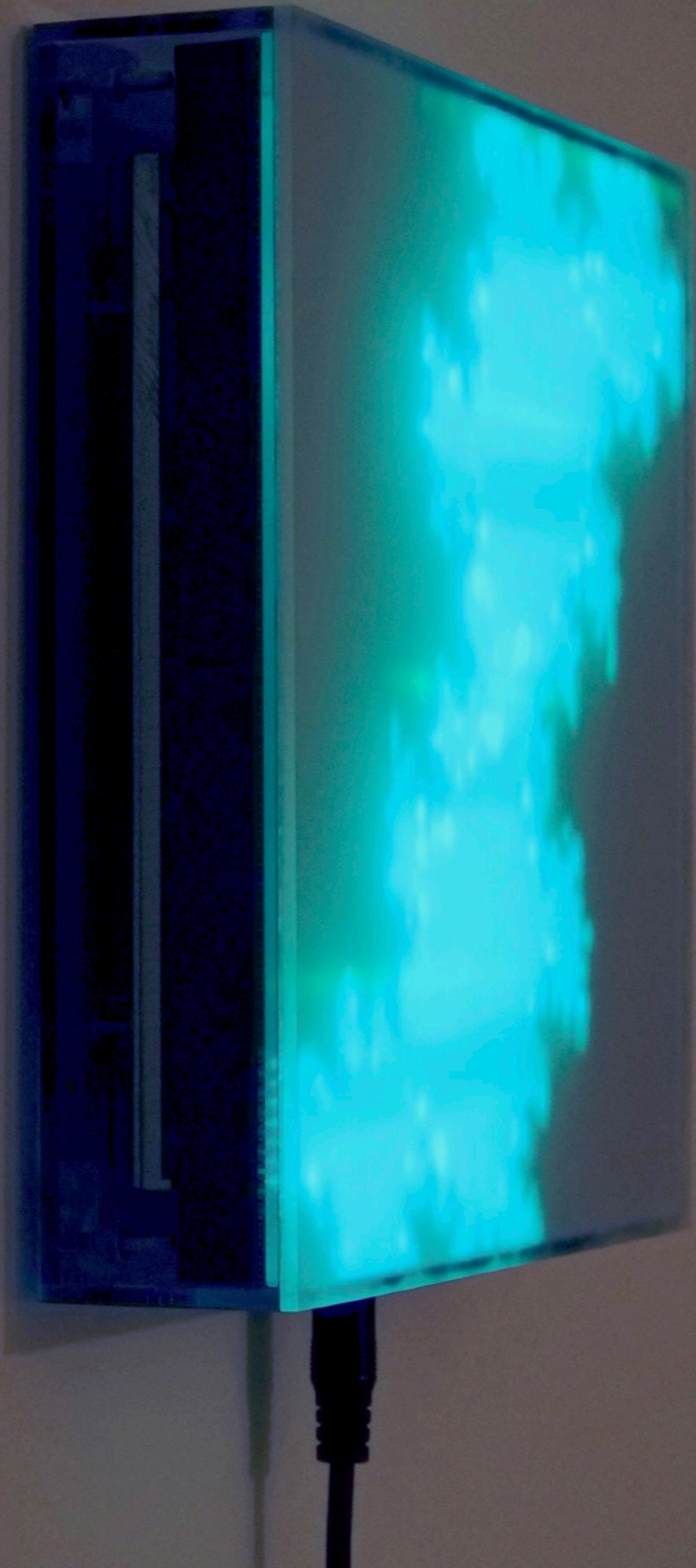
2. **Methods of Record-Keeping**  
There are several methods used for record-keeping, each with its own advantages and disadvantages. These include manual filing, digital storage, and hybrid systems. The choice of method depends on the nature of the business and the volume of records. Digital storage offers the advantage of easy access and searchability, while manual filing is often preferred for its security and reliability.

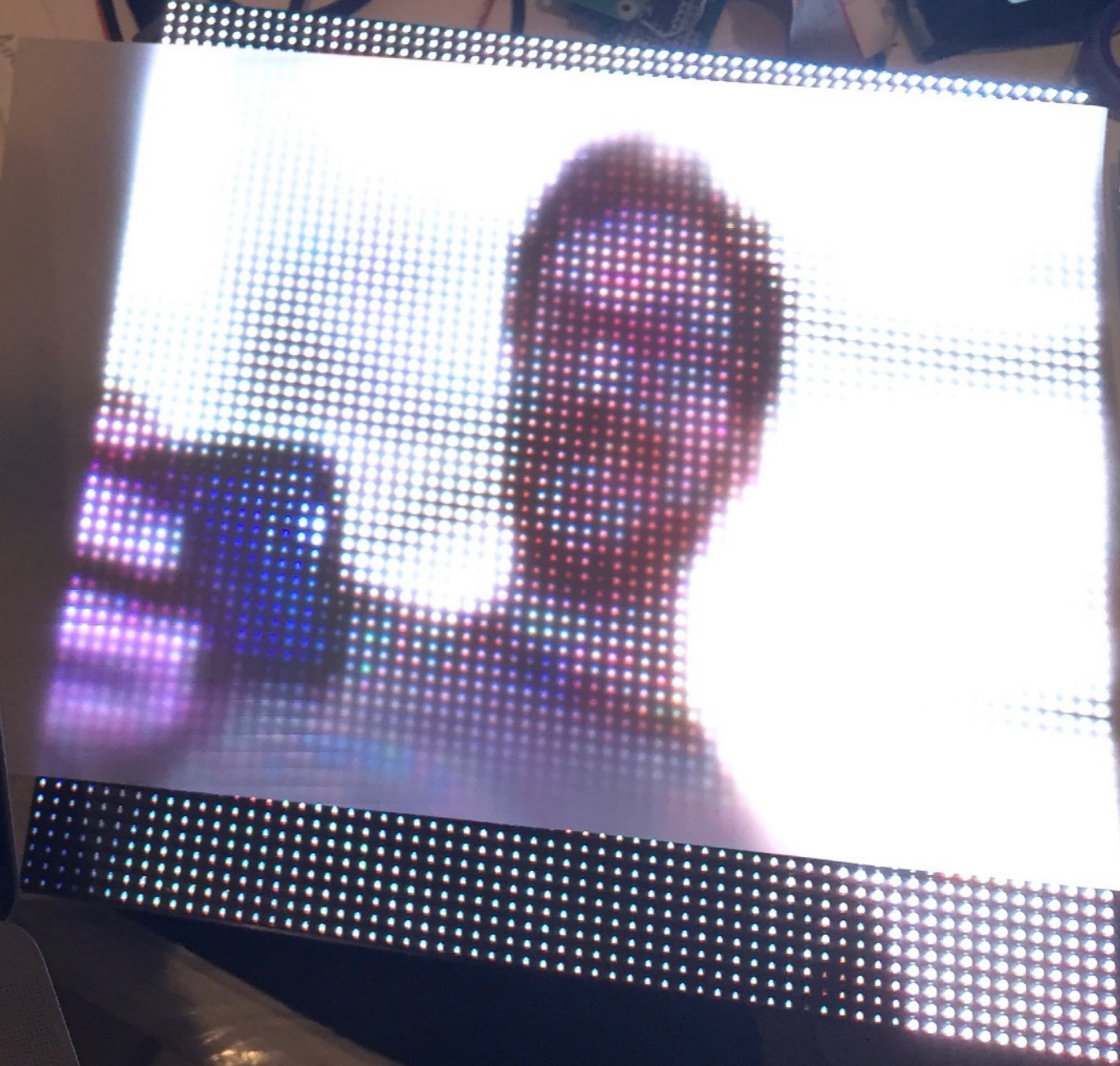
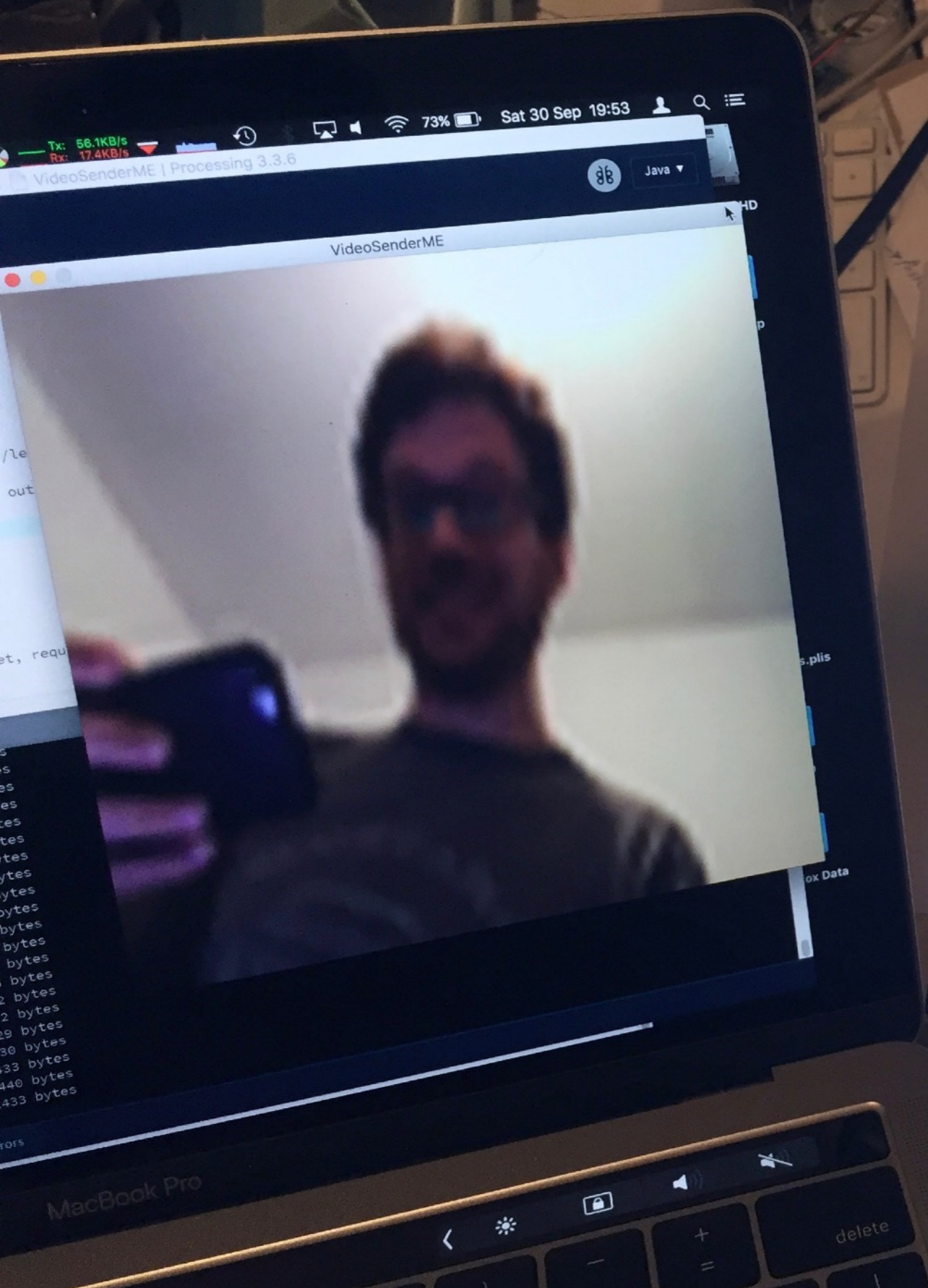
3. **Benefits of a Well-Organized System**  
A well-organized record-keeping system offers numerous benefits to a business. It improves efficiency by making it easier to find information when needed. It also enhances security by ensuring that records are stored in a safe and secure manner. Additionally, a good system can help in compliance with legal requirements and provide valuable insights into business operations.

4. **Conclusion**  
In conclusion, maintaining accurate records is a critical component of any business. It is essential for the smooth operation of the organization and for the protection of its assets. By implementing a well-organized record-keeping system, businesses can ensure that they are always up-to-date and ready to meet any challenges that may arise.











Connected to  
10.10.10.128

testpi.house

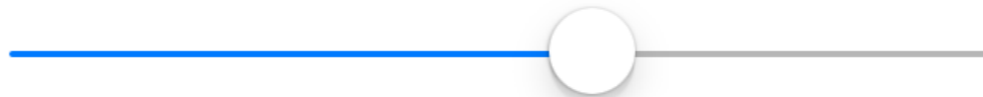
Snapshot

Sending video

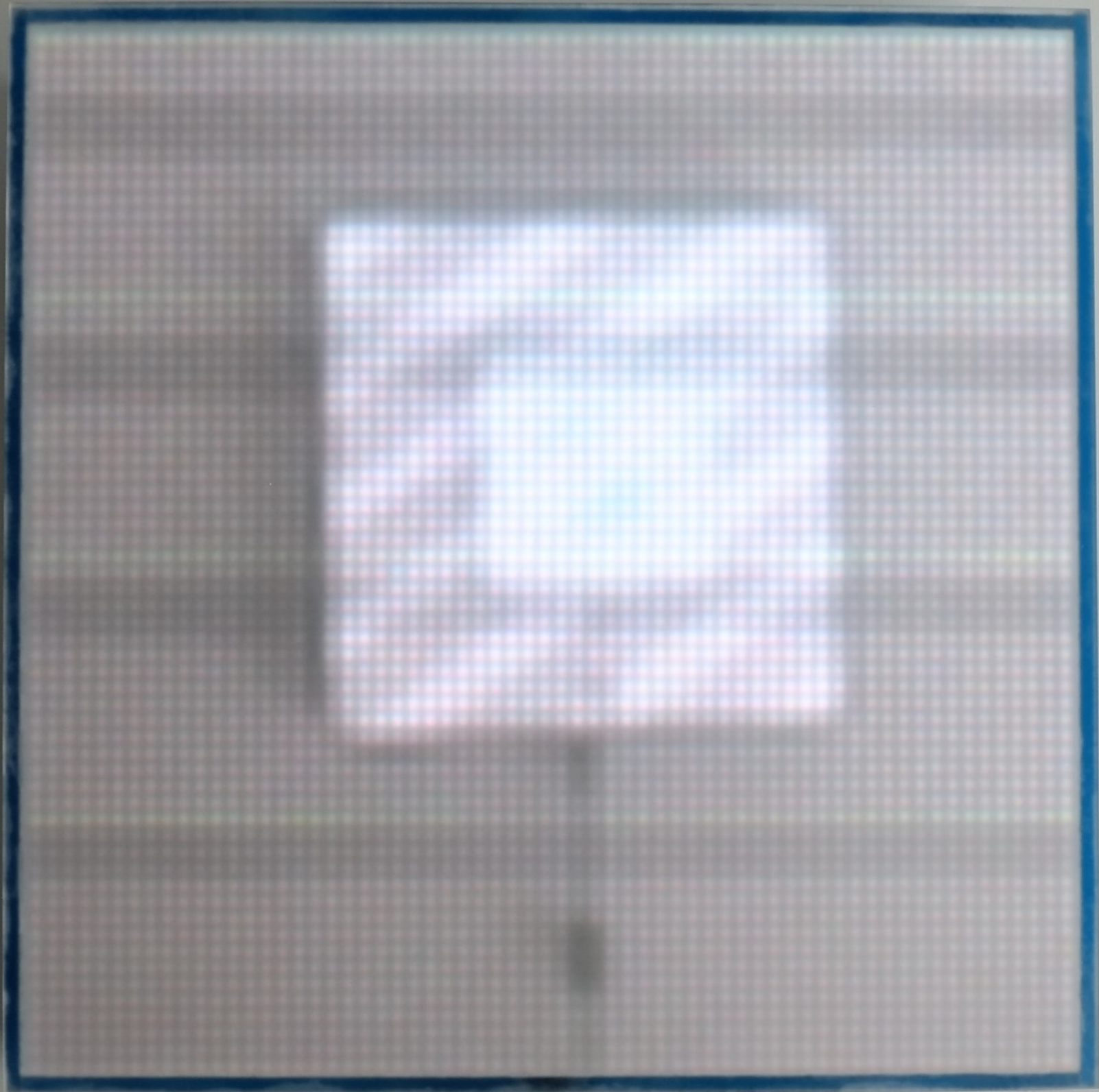
Effect



Gamma







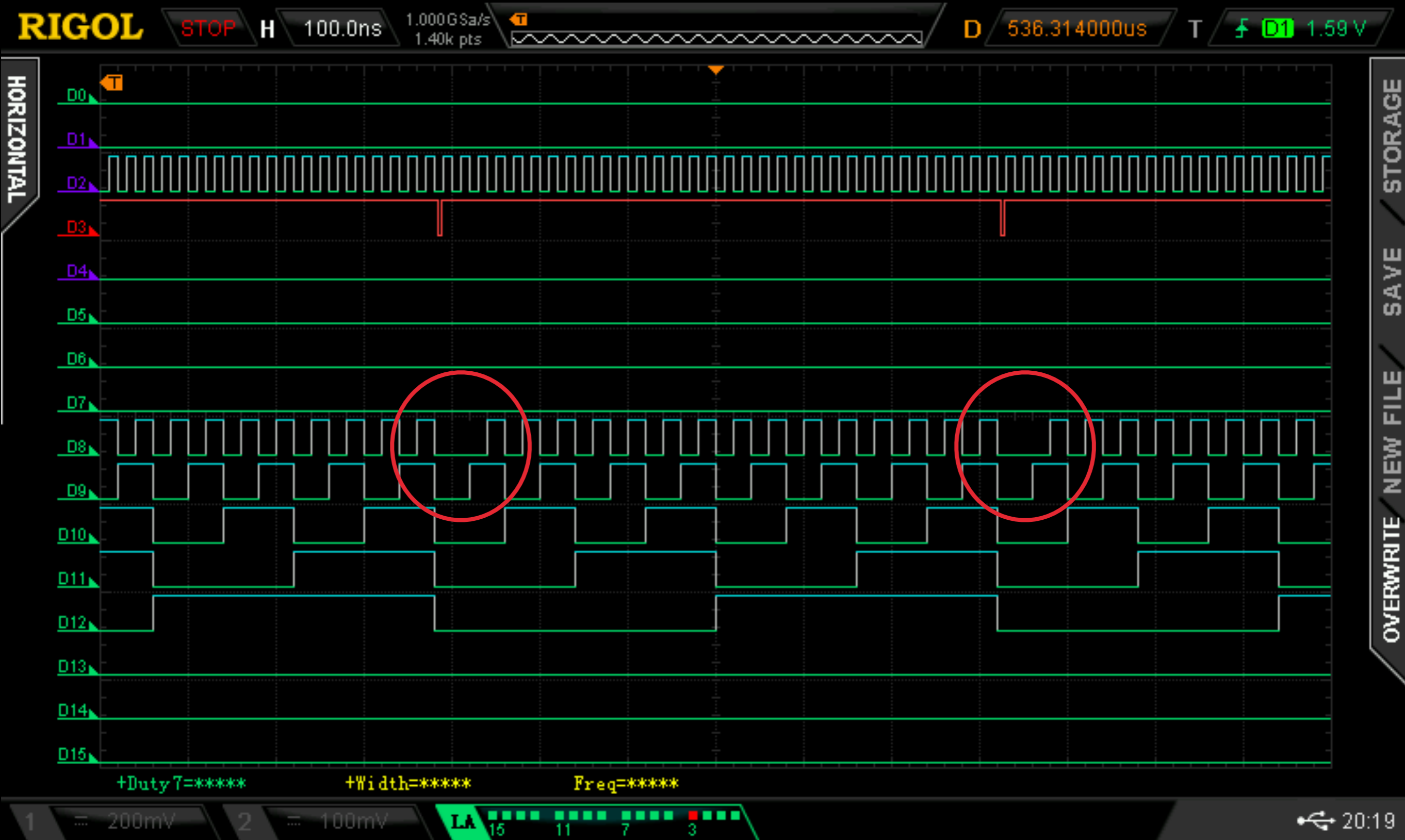
So, it's perfect!



# Not quite — some quirks

- 24 bit DPI uses *all* GPIOs
  - DeviceTree configures per-pin multiplexing — you don't *have* to use them all
- I used a 16BPP screen mode — I only needed a few bits output
  - But where's my LSB of Blue?

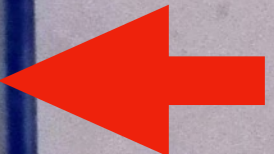
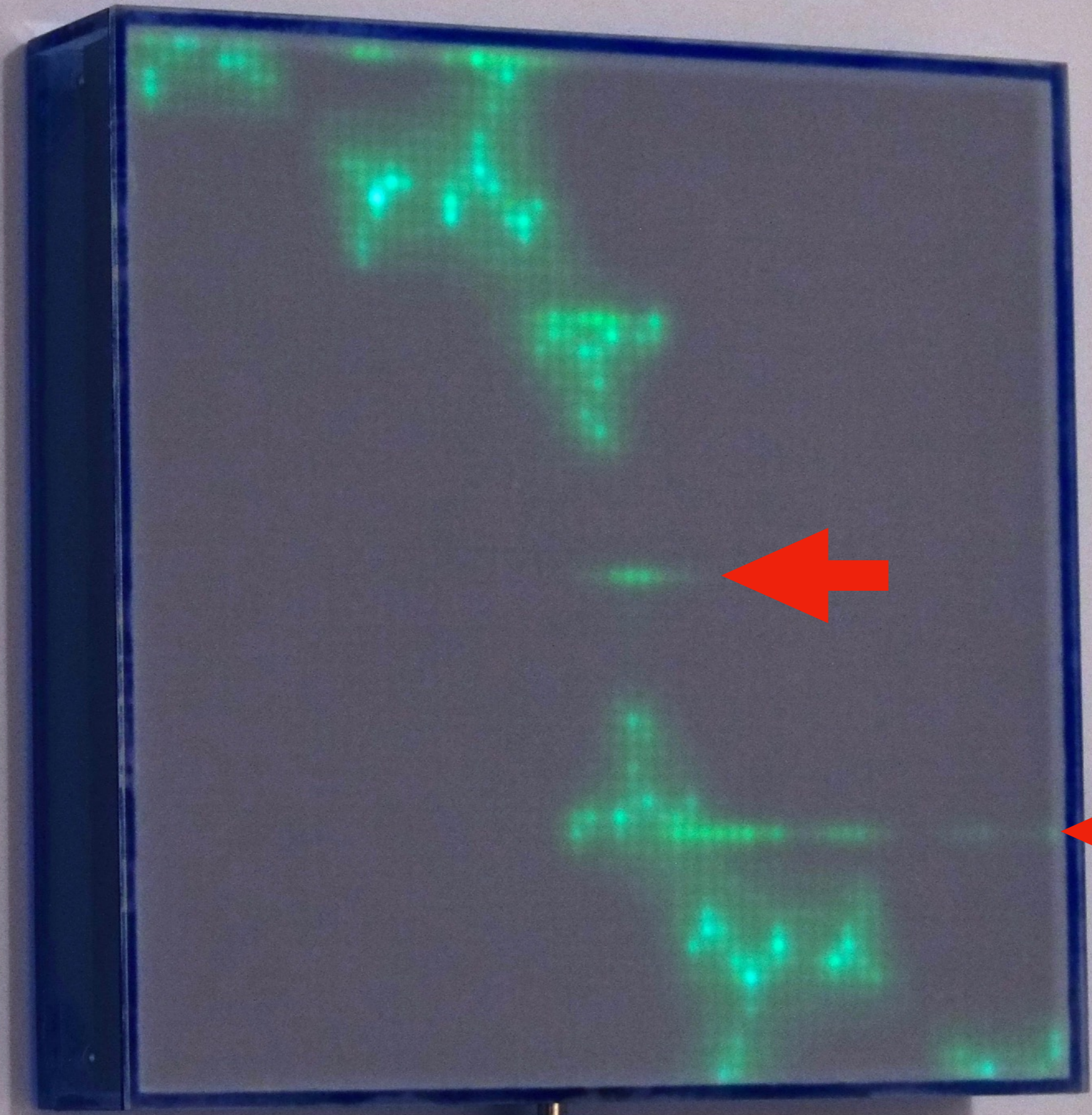
# Lost blue bit





# Lost blue bit

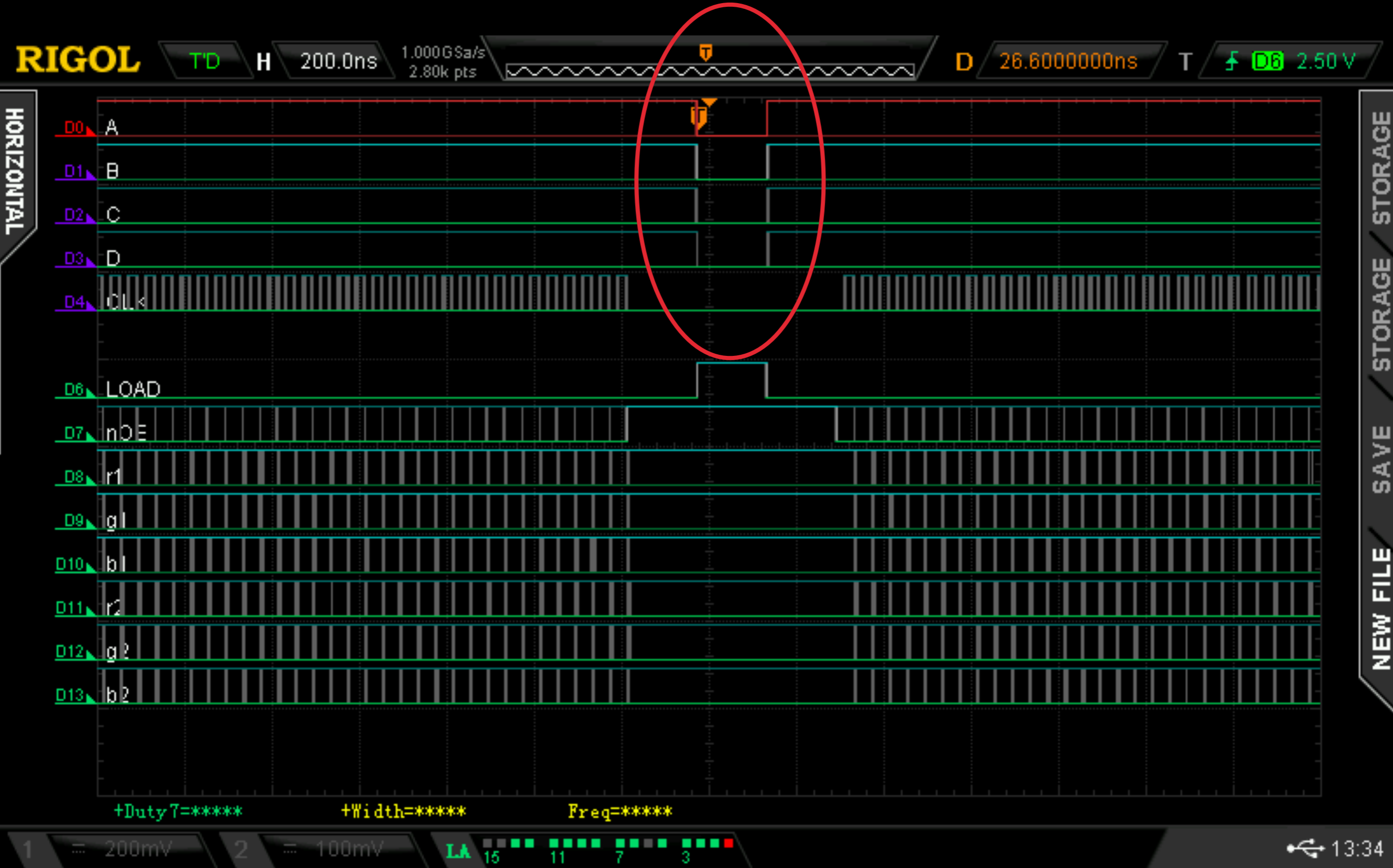
- My theory: display controller doing post-framebuffer dithering/colour correction in 16BPP modes
- This does not occur in 32BPP modes — I recommend just using 32BPP!





# Signals not (all) held across Hsync

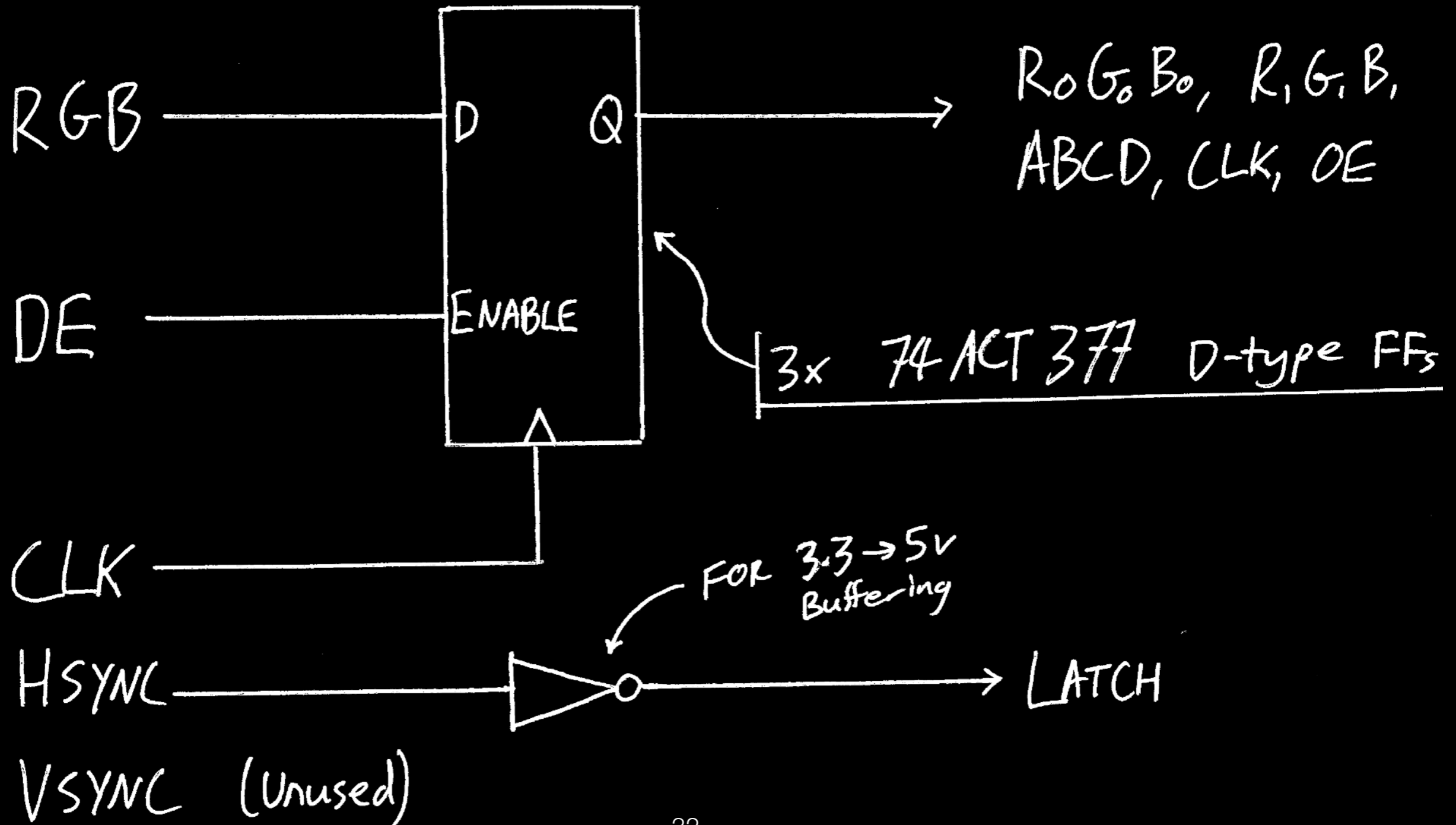
(but some are...)



# v2 circuit

RP: DPI (3.3v)

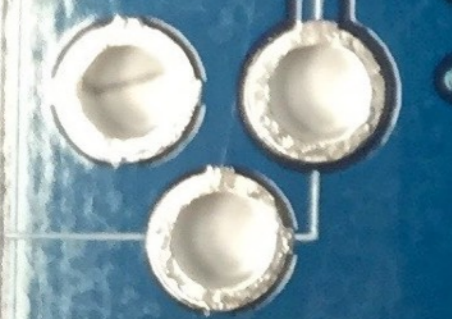
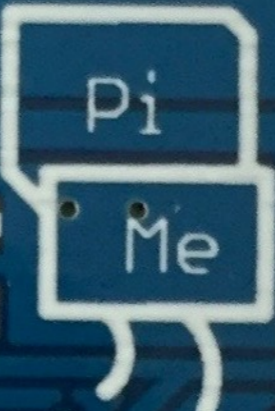
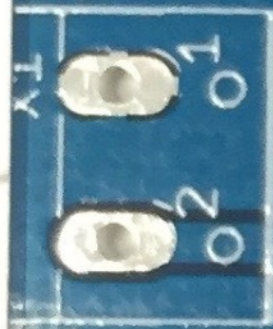
HUB75 (5v)



Hub75Hat r0

GPIO

Matt Evans  
290318



HUB75 1:16



DISP1



DISP0

# Enabling DPI

- OK Matt, DPI sounds *amazing*, how do I use it?
- <https://www.raspberrypi.org/documentation/hardware/raspberrypi/dpi/README.md>
- Enabled through `/boot/config.txt`
- Then, just write the display framebuffer as usual

```
dtoverlay=dpi18
enable_dpi_lcd=1
display_default_lcd=1
framebuffer_depth=16
# HS/VS phase (0) polarity (0) control (7), nCLK/DE (2),
# RGB order(1), 565 mode 3 (3):
dpi_output_format=0x007213
# Custom timings
dpi_group=2
dpi_mode=87
# hdmi_timings=<h_active_pixels> <h_sync_polarity> <h_front_porch>
# <h_sync_pulse> <h_back_porch>
# <v_active_lines> <v_sync_polarity> <v_front_porch> <v_sync_pulse>
# <v_back_porch> <v_sync_offset_a> <v_sync_offset_b>
# <pixel_rep> <frame_rate> <interlaced> <pixel_freq> <aspect_ratio>
hdmi_timings=272 0 0 8 0 1103 0 1 1 100 0 0 0 170 0 60000000 1
```



# BCM2835 DPI capabilities

<b>Pixel clock</b>	min 32MHz, 105MHz tested OK Maximum ~150MHz?
<b>X pixels</b>	min 8 max 1920
<b>Y pixels</b>	min 8 max 1280
<b>Sync widths</b>	min 1 pixel for HS min 1 line for VS
<b>Misc</b>	Didn't check max sync widths or lowest frame rate (theoretically 14Hz)

# Many other computers support similar LCD video output

- Common for SBCs to have parallel output from LCD controller!
  - Beagleboard, various cheap Allwinner/sunxi boards
- I like this technique because:
  - Often faster than GPIO
  - Realtime, zero CPU overhead
  - Much easier to get started/debug than using DMA controllers
  - Can do this from **userspace**, or even python
- Not as nice as a Beaglebone PRU ;- ) (But \$\$\$/complicated!)

# Aside from VGA and LCDs and LEDs, what is it good for?

- Supply data to FPGA/CPLD — pattern/signal generator?
- Motors — 24 servos!
  - Steppers?
- Drive 20 SPI LCDs at once
- Or 24 strings of WS2812s — 24x1024 at >30fps!
  - Only 1.2kW & about €2000 🤔

# Goodbye

- Some ideas for cool things to do with LEDs?
- Try using DPI/TFT controllers for unusual purposes?
- Look at peripherals on your boards — any opportunity for creative misuse?

Thank you!



More hax!

<http://axio.ms>

<https://github.com/evansm7>