Monotron

Embedded Rust and the

- Jonathan 'theJPster' Pallant
- ACCU, April 2019

Preamble: Introductions

- @therealjpster (Twitter)
- @thejpster (Github)
- keybase.io/thejpster

Preamble: What can I expect?

- A tale of obsession
- Right tool, to fix the wrong thing

Agenda

- Act 1 - Embedded Rust <--
- Act 2 - The Idea
- Act 3 - The Implementation
- Act 4 - Spiralling out of control
- Act 5 - The Demo


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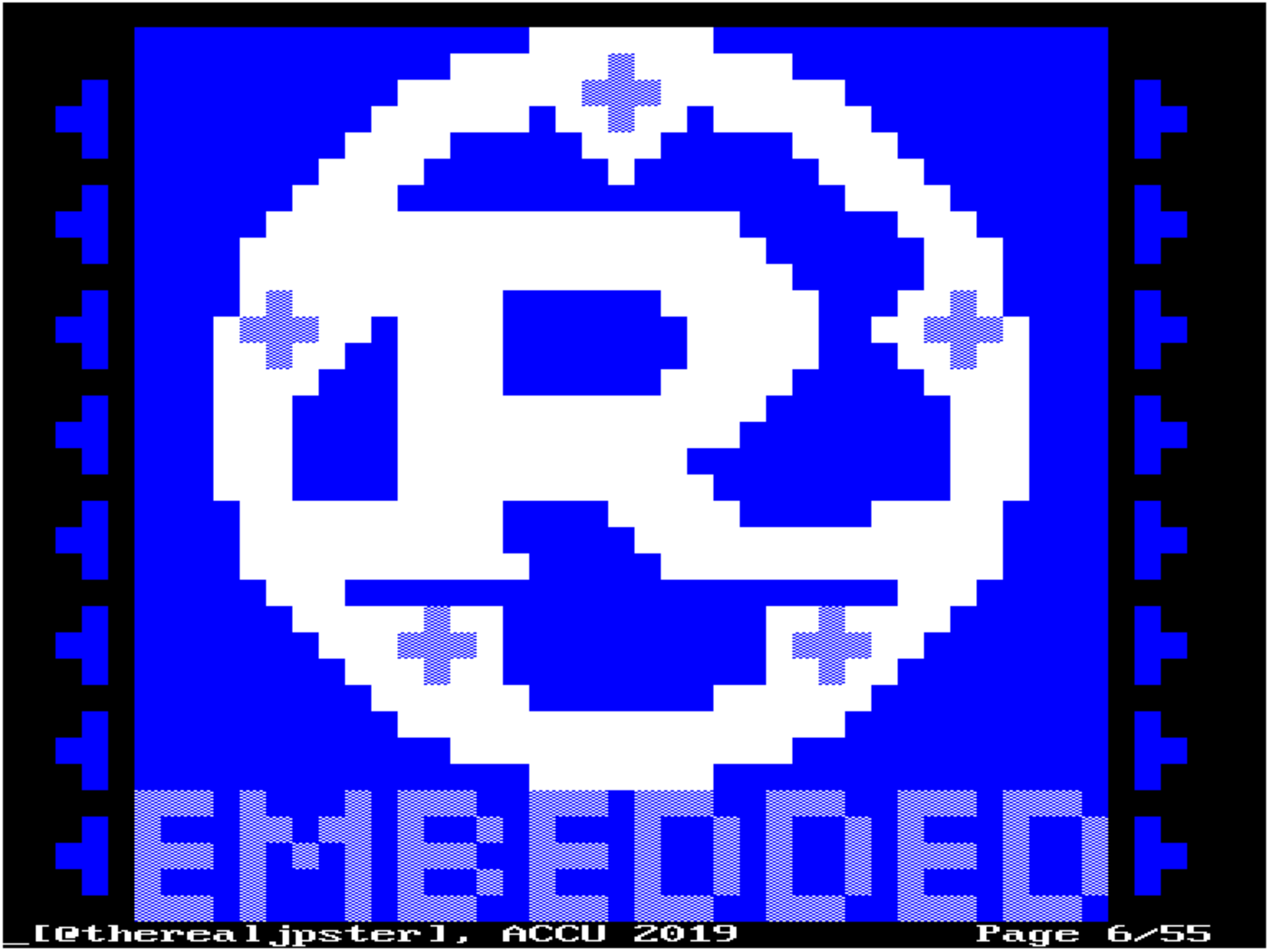
Page 5/55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Page 6/55


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Act 1: Rust 2018
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Act 1: Things you need for Embedded Rust

1. LLVM Backend
2. Target File
3. libcore

Act 1: UART / GPIO Example

```
// USB Serial UART
let mut usb_uart = Serial::uart0(
    p.UART0,
    porta.pa1.into_af_push_pull::<gpio::AF1>(
        &mut porta.control
    ),
    porta.pa0.into_af_push_pull::<gpio::AF1>(
        &mut porta.control
    ),
    (),
    (),
    115200_u32.bps(),
    NewlineMode::SwapLFtoCR,
    &clocks,
    &sc.power_control
);
```

Act 1: Atomic Section / Closures Example

```
pub fn free<F, R>(f: F) -> R
where
        F: FnOnce(&CriticalSection) -> R,
{
        let primask = register::primask::read();
        disable();
        let r = f(unsafe {
                &CriticalSection::new()
        });
        if primask.is_active() {
                unsafe { enable() }
        }
        r
}
```

Act 1: Deref / Memory Mapped I/O Example

```
impl CBP {

    pub (crate) unsafe fn new() -> Self {
        CBP {
            _marker: PhantomData
        }
    }

    pub fn ptr() -> *const RegisterBlock {
        0xE000_EF50 as *const _
    }

}

impl ops::Deref for CBP {
    type Target = RegisterBlock;

    fn deref(&self) -> &Self::Target {
        unsafe { &*Self::ptr() }
    }

}
```

Act 1: Creating a new Project

- cargo new my_project
- Clone rust-embedded/cortex-m-quickstart
- cargo generate

Act 1: Adding a HAL crate

- Hardware Abstraction Layer
- Some crates will Use the HAL...
- `fn new(spi: S) where S: spi::FullDuplex`
- Some crates will Impl the HAL...
- `impl spi::FullDuplex for TivaSPI {...}`
- Serial Ports, I2C, SPI, Timers, etc.

Act 1: Running Embedded code on an OS

- Anyone can impl the Hal...
- impl spi::FullDuplex for LinuxDev {...}
- #[cfg(feature)] macros

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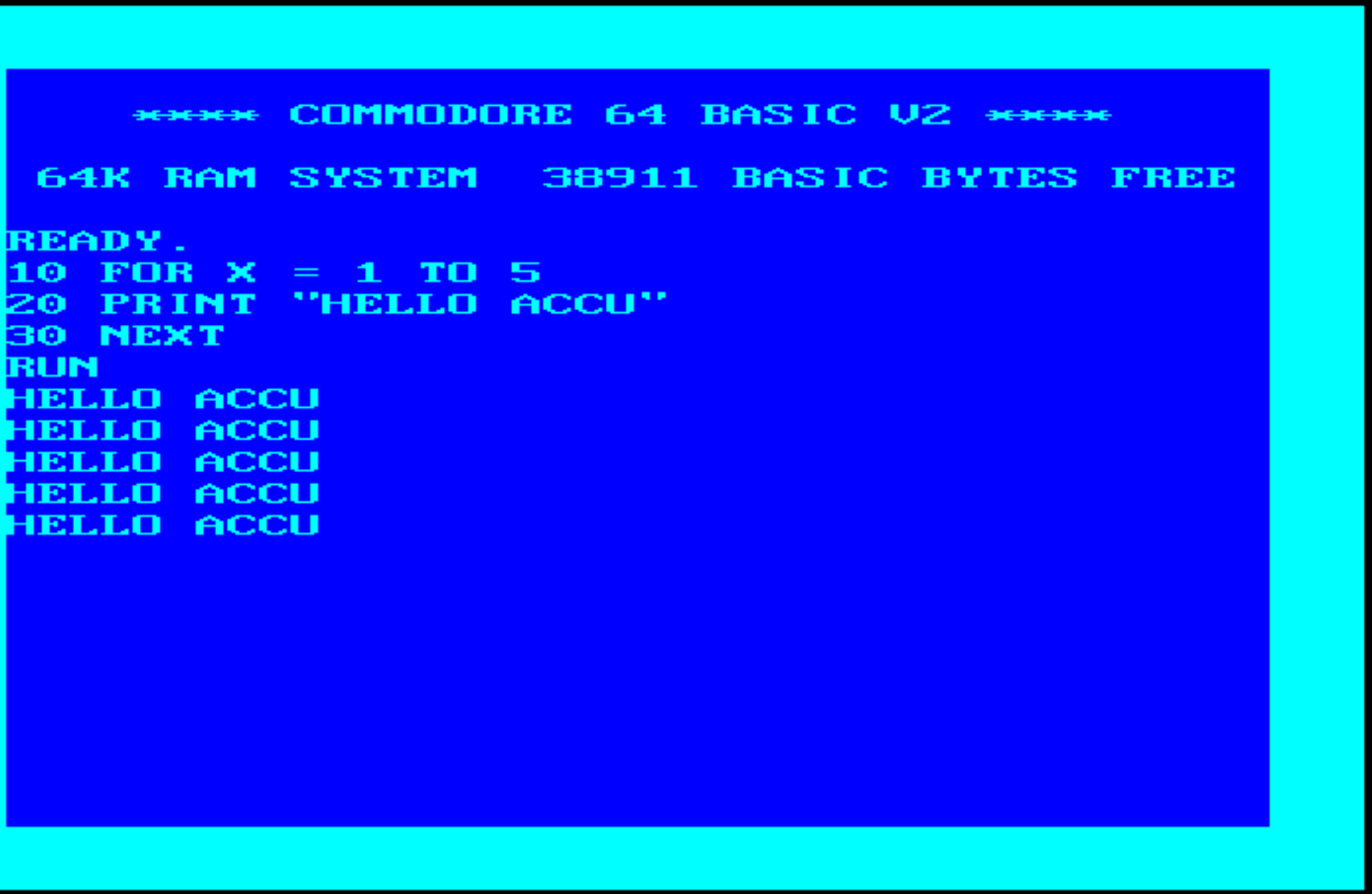
Act 2: The Commodore 64

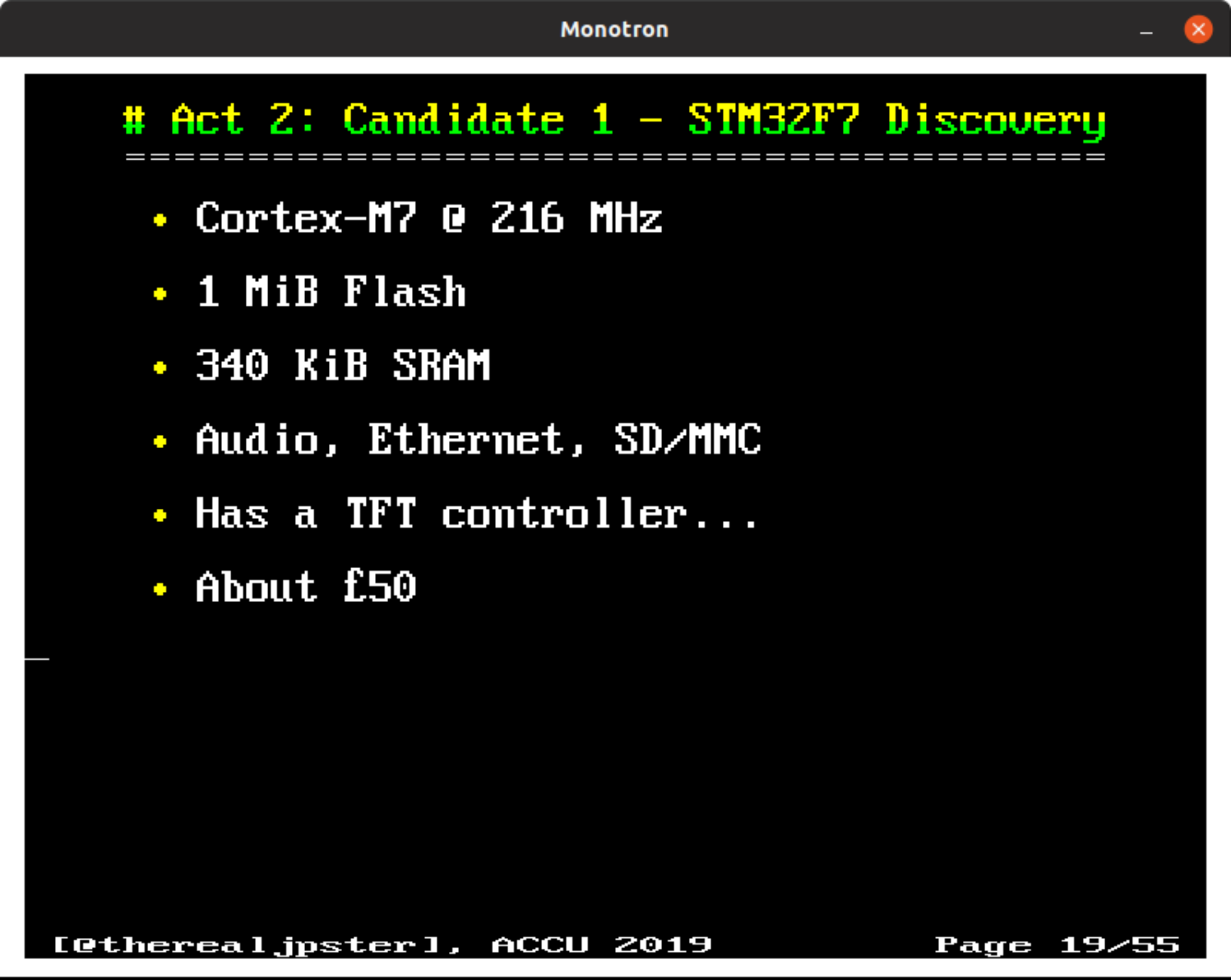


Act 2: Less is More

- For Sale: Baby shoes, never worn

Act 2: Goals for the project

- To distract me...
- Can you generate video with Rust?
- How much can you squeeze from one chip?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Act 2: Candidate 1 - STM32F7 Discovery
• Cortex-M7 @ 216 MHz
• 1 MiB Flash
• 340 KiB SRAM
• Audio, Ethernet, SD/MMC
• Has a TFT controller...
• About £50
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STM32F7 Discovery
==========
STM32F7
DISCOVERY
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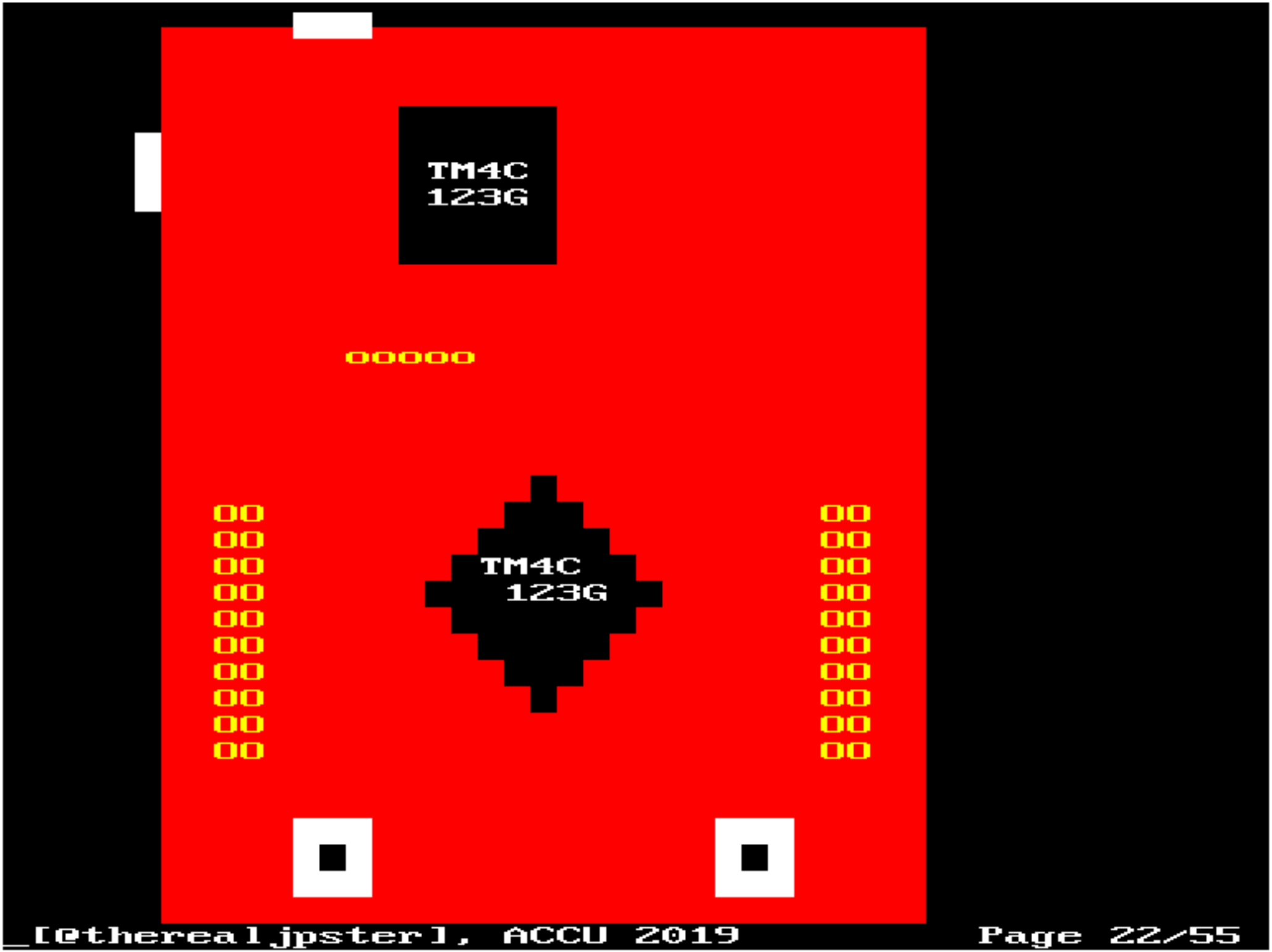
Page 20/55

Act 2: Candidate 2 - Stellaris Launchpad

- Cortex-M4 @ 80 MHz
- 256 KiB Flash
- 32 KiB SRAM
- I2C, UART, SPI
- About £12
- There was one on my desk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TM4C
123G
TM4C
123G
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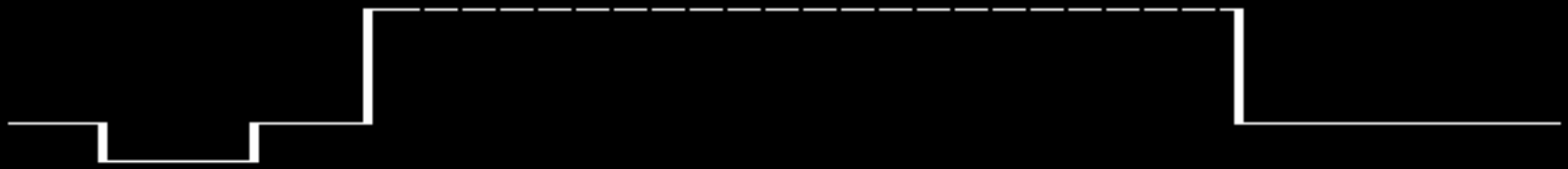
Act 2: Generating Analog Video

Act 2: VGA Timing

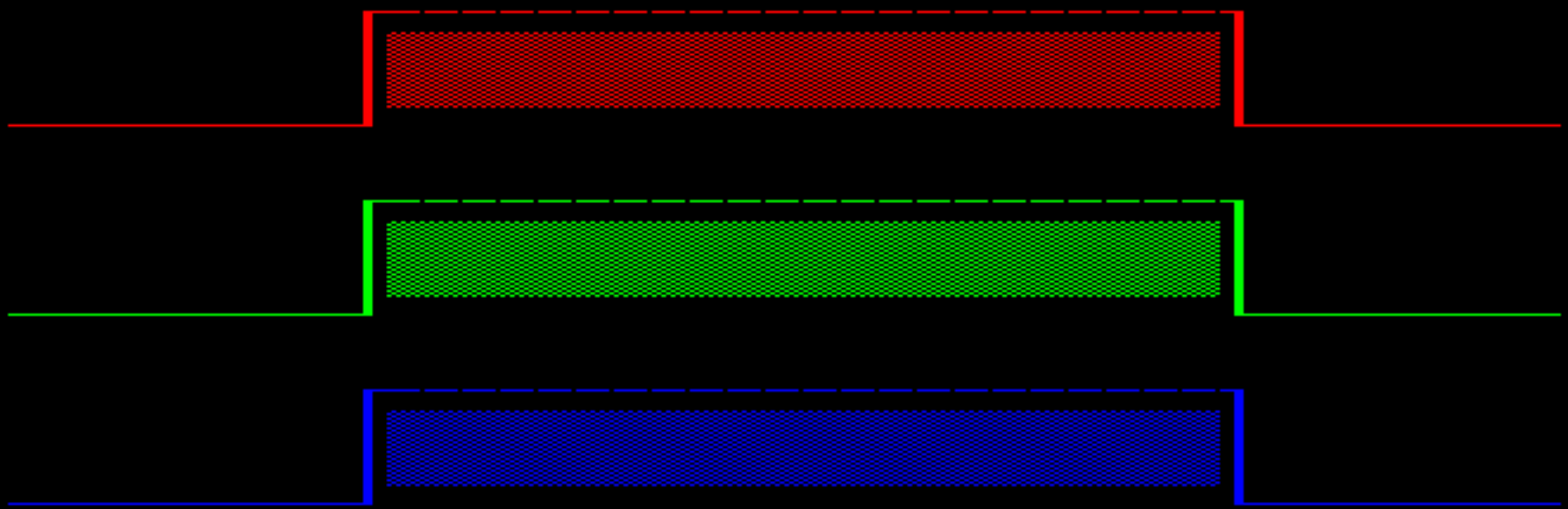
- tinyvga.com/vga-timing
- 640 x 480 @ 60 Hz = 25.175 MHz
- 720 x 400 @ 70 Hz = 28.322 MHz
- 800 x 600 @ 60 Hz = 40.000 MHz

Act 2: Rendering Mono/RGB Bitmaps

- Mono analog video



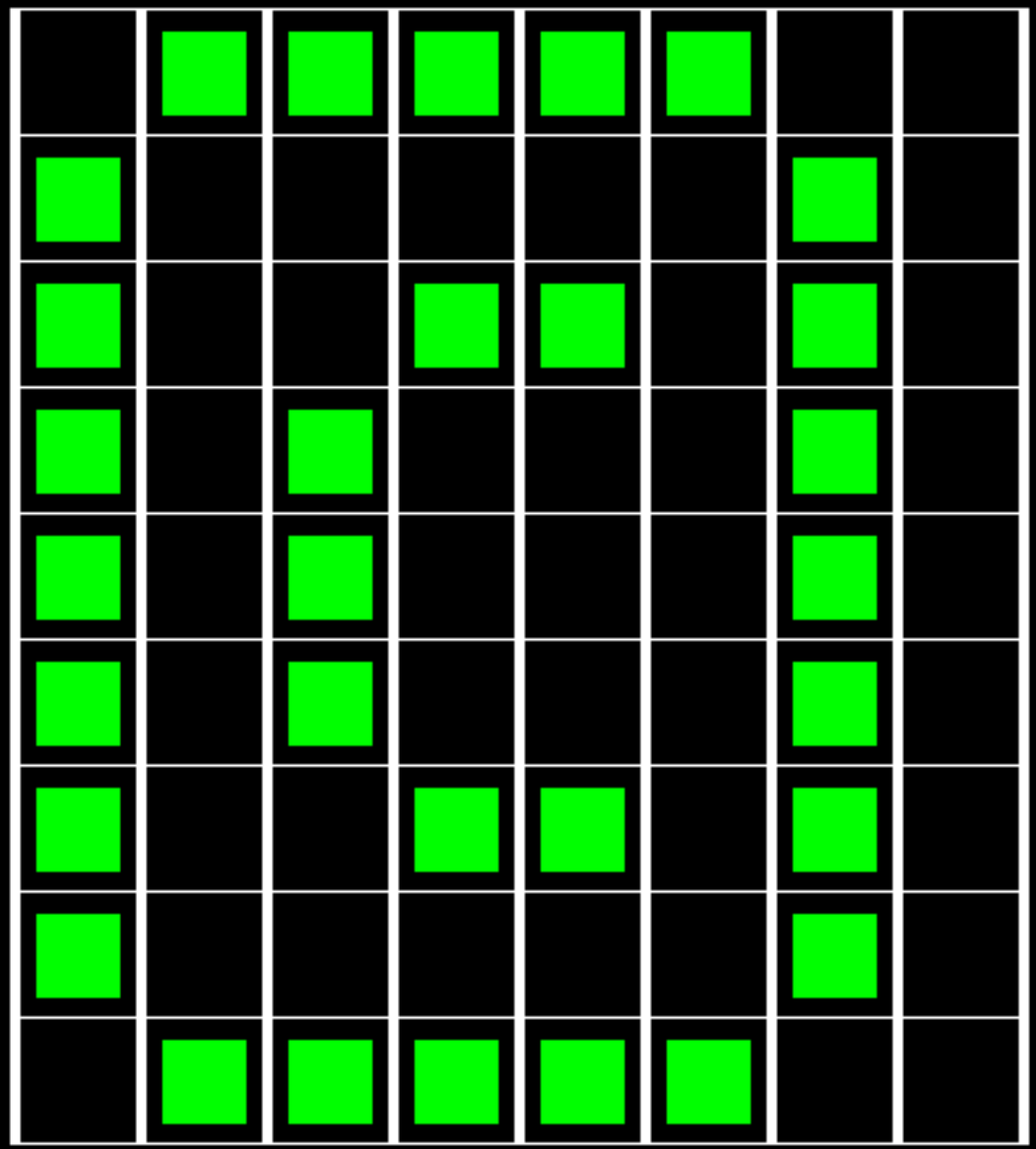
- RGB analog video



Act 2: Text Mode

- A Font is a collection of tiny bitmaps
- Code Pages vs Unicode
- Rendering to a bitmap or in real-time

Act 2: Text Attributes



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Act 2: Show me the source!

```
for (ch, attr) in row.glyphs.iter() {
    let index = (*ch as isize) *
        (MAX_FONT_HEIGHT as isize);
    let w = unsafe {
        *font_table.offset(index) };
    let rgb_addr = unsafe {
        RGB_MAPS
            .as_ptr()
            .offset(
                (
                    (attr.0 as isize) *
                    256_isize
                ) + (w as isize)
            )
    };
    let rgb_word = unsafe { *rgb_addr };
    hw.write_pixels(
        rgb_word >> 16,
        rgb_word >> 8,
        rgb_word
    );
}
```

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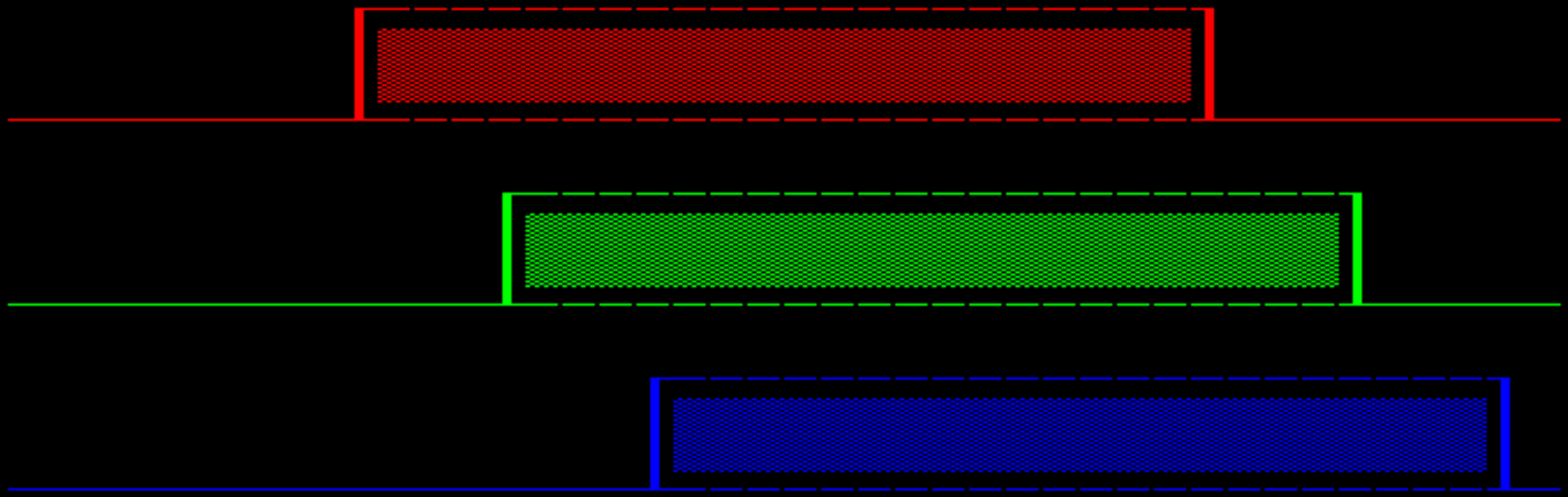
Act 3: Implementation Failure...



- Fringing effect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Act 3: Would you like to see a demo?
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Act 3: Serial Input

- Keyboards are tiny computers
- Talking to them is non-trivial
- So, I cheated...

Act 3: Command Line Interface

- REPL?
- BASIC?
- Keep it simple...

```
Item {
   item_type: ItemType::Callback(beep),
   command: "beep",
   help: Some("<freq> <len>"),
},

> beep
Error: Not enough arguments

> beep 440 60
Playing 440 Hz for 60 frames
```

Act 3: PS/2 Keyboard (fail!)

- Clock Signal (from Keyboard)
- Data Signal (bi-directional)
- Open-Collector (can hold clock low)
- Scan Codes, ugh!
- Interrupts @ 10 kHz are bad for video


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Act 3: Joystick
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Act 3: Memory Layout

Act 3: Application Binary Interface

- 0x2000 - 0x2003: Pointer to init fn
- 0x2004 - 0x2FFF: Don't care!
- Structure of function pointers

Act 3: Application Binary Interface

- putchar(char) -> int
- puts(const char*) -> int
- readc() -> int
- wfvbi()
- kbhit() -> int
- move_cursor(row, col)
- play(freq, chan, wave, vol) -> int
- change_font(font)
- get_joystick() -> u8

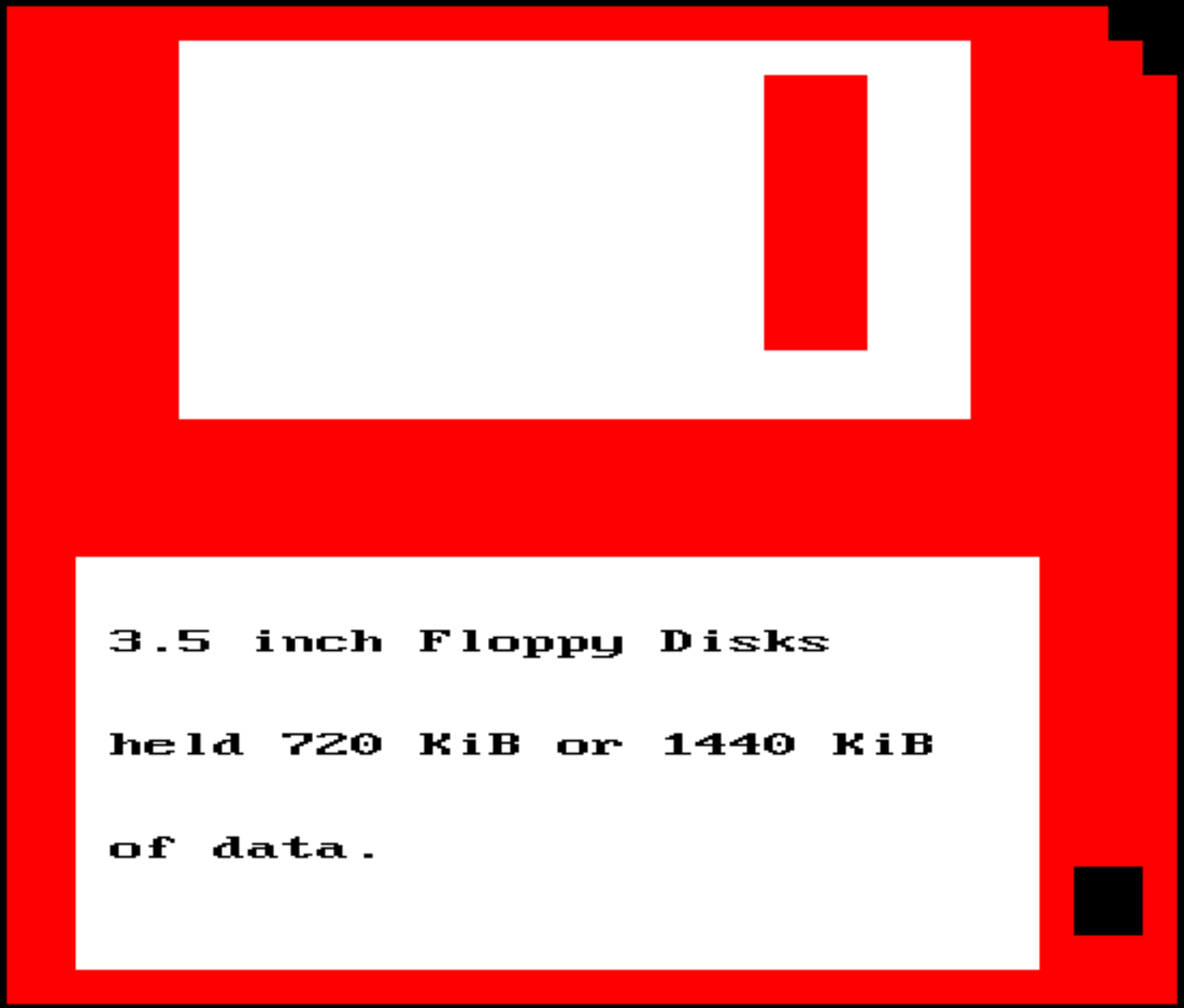
Act 3: Audio

- Square Wave Beeps

- PWM and Audio Filter

- Basic Tunes
- Three-channel wavetable synthesiser
- Tested on Linux with Pulse Audio

Act 3: Storage Options



Act 3: Microsoft FAT Filesystems

Act 3: SD Card

- Appear as an array of 512-byte blocks
- Can be partitioned (or not)
- Can work in SPI mode (slowly)

- Super cheap!
- GH: thejpster/embedded-sdmmc-rs

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Act 4: Demo veroboard

Act 4: Designing a PCB

- Is...
- ...hard
- ...really time consuming
- ...an open-ended project
- ...quite good fun?

Act 4: RS-232 Serial Port

- It's not a DB9!
- +/- 5V to 15V signalling
- RX / TX / GND
- RTS / CTS
- DTR / DSR
- RI / DCD

- Could hook up old Modems?
- Serial mice?
- Linux on Monotron!

Act 4: MIDI Port

- Atari ST had one...
- MIDI is just a UART!
- 31,250 bps
- 5V signalling, opto-isolated

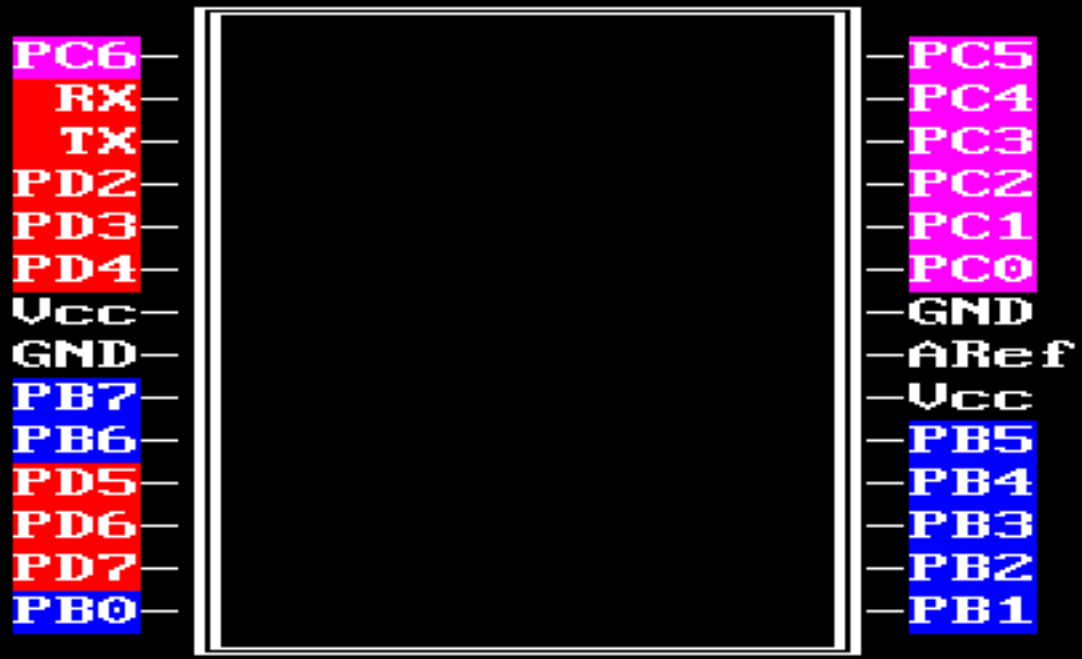
Act 4: Real Time Clocks

- CMOS Batteries
- TM4C has one...
- ... but no coin cell input
- Crystal capacitance is fun
- Inter-Integrated Circuit / TWI
- Sec/Min/Hour/DOW/Day/Month/Year

Act 4: Keyboards, revisited

- Can't do 10 kHz data AND video
- How did IBM solve this?
- Intel i8042
- I could add an I/O processor!

Act 4: AtMega 328



- 23 pins ...
- (If you include RST and XTAL1/2)

Act 4: IEEE-1284 Parallel Port

Act 4: Inventing a programming language

- BASIC
- Python
- Javascript
- Pascal
- REXX
- Euphoria

Act 4: Monotronian

```
01 fn main(args)
02     len = length(args)
03     for x = 1 to len
04         if args[x] == "--help"
05             print_help()
06             return
07         elif args[x] == "--verbose"
08             verbose = verbose + 1
09         else
10             process_file(args[x])
11         endif
12     endfor
13 endfn
```

Act 4: Closing Thoughts

- github.com/thejpster
- keybase.io/thejpster
- Come say hi!
- (I have Rust Embedded flyers)
- Think about how you write code

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