



# Seth Journal

## Week 15

WE DONE (almost)

### Entry 6

10:15am-7pm

4/25 Friday

8.75 hours

Ok, was unable to solve with Brian last night what caused the pio machine not to work

For the first part of today without Brian, i decided to reimplement in a new RAM module the original code instead of trying to integrate the original bus code with the RAM file. I ran that however it still failed due to borrowing issues. Chatgpt kept using take() and unwrap() to pass the references to the RAM object without dropping them:

```
let mut sm0 = pio1.sm0.take().unwrap();  
let mut sm1 = pio0.sm1.take().unwrap();  
let mut sm2 = pio0.sm2.take().unwrap();  
let mut irq2 = pio0.irq2.take().unwrap();
```

However, the state machines do not allow them to be taken or unwrapped so this did not work.

I then tried another approach that was close to the original implementation where I used closures inside the main loop instead of making a struct cause I anticipated references were getting dropped. That worked.

I then tried calling the closures from inside of a RAM class like this in order to be able to have methods that could be called by the CPU class to do read and write operations on

```

let write: impl FnMut(u32, u8) -> impl Future<Output... = async |address: u32, data: u8| {
    // set address to output and data to output pindirs
    sm2.tx().wait_push(0xFFFFF).await;

    info!("Initiating write of 0x{:02X} to address 0x{:08X}", data, address);

    let value: u32 = (address << 8) | (data as u32); //| if en {0x80000000} else {0x00000000};

    sm2.tx().wait_push(value as u32).await;

    irq2.wait().await;
    // set address to output and data to input pindirs
    sm2.tx().wait_push(0xFFFF0).await;
    info!("Write complete to address 0x{:08X}", address);
};
struct R {
    defmt_macros
    proc_macro write
}
impl RAM {
    fn w {
        write()
    }
}

```

can't capture dynamic environment in a fn item  
use the `|| { ... }` closure form instead rustc(Click for full compiler diagnostic)

View Problem (Alt+F8) Quick Fix... (Ctrl+.) Fix using Copilot (Ctrl+I)

As you can see though, I get an error that the dynamic environment can't be captured. So I don't think closures are the answer.

I then tried looking up other ways embassy can handle dynamically changing peripherals in other parts (functions) of the code.

I saw that [embassy-executor](#) provided functions for notating the main and task functions. I could store things in task functions, however that wouldn't really help as task functions are supposed to be run 24/7 and not listen exactly for requests.

I also found Mutexes, Channels, and interrupts. I found this in the [embassy book](#). I gave had chatgpt the examples and my code and had it try rewriting my code to use them to pass messages between the main thread and other running tasks that would handle reading and writing. It tried, however, it kept running into using `.take()` and `unwrap()` and didn't fully know how to use mutexes, so I didn't bother.

Brian then came around this time and I asked him to look into the problem because he is more experienced with Rust borrowing than I am. Over the next 2 hours and while we did our first demo he figured out how to use closures and keep them alive using the nightly Rust development channel so that we could have the reads and writes work. That approach worked.

We reconfigured all the old code to make the initialization of the RAM in the main function and then passed the closure-enclosed read and write functions to the CPU struct to be able to be called. We programmed the memory card with our original memory reading code and cpu card with the new RAM-using transaction code. This worked! We saw the correct instructions written to memory during the `mem_init()` phase and then the CPU using its program counter to do reads from memory, pull the correct instructions, and execute them!

While this was done/after our demo Caleb who was working on the front panel and got the single step/run working ish had to leave, so I took over from him on this. We needed to get single step and stuff working before our chance at a second demo so I needed to fix his code.

I decided to change around the signals a bit and how they were used. I discarded PRDY and just used CLK, PRESET, and PANEL to control RUN, STOP, RESET, and single step. If the STOP button was pressed on the front panel, PANEL would be set high and the front panel would be in control of the data bus and the computer would be in stop mode. You could use the SINGLE STEP button to step through the program. This would trigger a positive edge on the CLK line every time it was pressed and the CPU would watch for it to advance an instruction. If RUN was pressed, PANEL would be set low, and the CPU would know to resume running its normal execution loop on its own. If RESET is



pressed on the front panel, this would tell the CPU to stop execution and reset its program counter, nomatter whether it's in run or stop mode. This operating logic was written out on the front panel and interchange side like this:

```

clock.set_low();
rst.set_high();

if get_reset(button_b_edges) {
  rst.set_low();
  info!("RESET triggered!");
  run_mode = false;
}
else if get_stop(button_a_edges) {
  panel.set_high();
  run_mode = false;
  info!("STOP triggered");
}
else if get_run(button_a_edges) {
  panel.set_low();
  run_mode = true;
  info!("RUN triggered");
}
else if get_singstep(button_a_edges) && run_mode == false {
  clock.set_high();
  info!("STEP triggered");
}
// else if get_deposit(button_b_edges) && run_mode == false {
//   info!("DEPOSIT triggered");
//   // get address from gpios
//   let address = read_address_from_pins(&mut a_pins);
//   // get data from switches (LSBs of address). slice address
//   let data = address & 0x00FF;
//   // set data pins as output
//   set_pins_as_output(&mut data_pins);
//   // push data to pins
//   for i in 0..8 {
//     if ((data >> i) & 1) != 0 {
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// reset master
if rst.get_level() == Level::Low {
  info!("Reset Occurred!");
  cpu.reset().await;
}

// running
if cpu.halted() {
  info!("CPU halted");
  hlt.set_high();
}
else {
  hlt.set_low();

  // run
  if panel.get_level() == Level::Low {
    // info!("cpu running...");
    cpu.unhalt();

    let instr: u8 = cpu.fetch_instruction().await;
    cpu.execute_instruction(instr).await;
    cpu.show_state().await;
  }
  // front panel has control
  else {
    if (clock.get_level() == Level::High) && (last_clk == false) {
      // cpu.disable_ram().await;
      info!("Single step Triggered!");
      let instr: u8 = cpu.fetch_instruction().await;
      cpu.execute_instruction(instr).await;
      cpu.show_state().await;
    }
  }
}

```

I tested this and the operations worked! I was likewise able to see in the terminal below when each buttons were pressed on the front card side and then the operation occurring on the CPU side.

Finally once brian finished his part, we integrated the RAM as well We pulled up the code and terminals for all 3 programs to be able to program and see their outputs a the same time:

```

interchangers.rs 9+ x diagnostic message [29] ...
164 fn main(spawner: Spawner) {
165     // default values for control signals, works well for
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We then tested it, saw the memory get programmed the computer go into stop mode, and then we were able to hit single step, run, stop, and reset to work through the program and memory reads and writes worked to the memory computer! This was our functioning computer!

We still had time before our demo so I got to work creating the deposit function while Brian fixed some of the LEDs on the front panel. The deposit function would let you enter in the switches on the front panel a data value you want to write to your current location in memory. It is one of the other front panel functions along with examine and protect that we had not implemented yet.

With deposit I needed draft out what signals would trigger on the bus and what data inputs to use to implement it. I came up with this draft plan:

- get addr from bus
- get data from switches
- output data on bus
- mwr bring low
- assert panel
- cpu should release output pins
- wait for xrdy to go high
- deassert mwr and output data

So the front panel needed to take over the mem write signal from the cpu. Since both can't be driven at the same time, I decided that the CPU would release control of the mem write line when it was in stop mode (PANEL high), but not single-stepping. However, the mem write line is a active-low line so it always needs to be driven high when not used. I couldn't just release control and have a gap when it's not high, so I set the mwrt pin to pull up on the cpu side with

```
Flex::new(p.PIN_6.reborrow()).set_pull(Pull::Up); // set mwrt as pull up
```

I then needed a way to release and regain output of the mwrt pin on the CPU side from inside the main loop. I tried adding

```
sm.set_pin_dirs(embassy_rp::pio::Direction::In, &[mwrt_pin]);
```

which suggestively would have told the state machine running the mwrt pin to stop it from outputting. However, this line faced a borrowing issue where you can't borrow sm a second time in the main loop. I needed to fix this or find another method. I decided another method. Brian helped me find that OUT\_EN\_SEL and INLINE\_OUT\_EN PIO configuration registers

23:19	<b>OUT_EN_SEL:</b> Which data bit to use for inline OUT enable
18	<b>INLINE_OUT_EN:</b> If 1, use a bit of OUT data as an auxiliary write enable When used in conjunction with OUT_STICKY, writes with an enable of 0 will deassert the latest pin write. This can create useful masking/override behaviour due to the priority ordering of state machine pin writes (SM0 < SM1 < ...)
17	<b>OUT_STICKY:</b> Continuously assert the most recent OUT/SET to the pins

These would allow us to control the output of the mwrt pin which was made a set pin and couldn't be controlled by pin\_dirs like normal. It was also simpler than making a second state machine for the mwrt signal.

We changed the state machine to use these:

```
cfg.out_en_sel = 0x1F;
cfg.inline_out_en = true;
cfg.out_sticky = true;
```

And then added a disable function in our front panel control to set a bit in the output to trigger the mwrt signal to turn off

```
else {
    if (clock.get_level() == Level::High) && (last_clk == false) {
        cpu.disable_ram().await;
        info!("Single step Triggered!");
        let instr: u8 = cpu.fetch_instruction().await;
        cpu.execute_instruction(instr).await;
        cpu.show_state().await;
    }
}
```

Next I needed to write the logic for gaining control and using the mwrt signal on the front panel side along with the other data inputs and bus control logic. Based on the psuedologic I wrote above, I came up with this code implementation:

```
else if get_deposit(button_b_edges) && run_mode == false {
  info!("DEPOSIT triggered");
  // get address from gpios
  let address = read_address_from_pins(&mut a_pins);

  // get data from switches (LSBs of address). slice address
  let data = address & 0x00FF;

  // set data pins as output
  set_pins_as_output(&mut data_pins);
  // push data to pins
  for i in 0..8 {
    if ((data >> i) & 1) != 0 {
      data_pins[i].set_high();
    } else {
      data_pins[i].set_low();
    }
  }
}

mwrt.set_as_output();
mwrt.set_low();

xrdy.wait_for_high().await; // wait for ready

mwrt.set_high(); // turn off write
mwrt.set_as_input(); // set back to input

// turn off data pins
set_pins_as_input(&mut data_pins);

Timer::after_millis(10).await;
}
```

I then programmed the front panel and cpu micros with the new code.

We tested the deposit button on a memor location with the switches all down. It wrote a zero, however, we were unable to step afterwards so something was either a bit broken with the logic or the bus lines like mwrt. Our final demo time came, so we excluded this functionality.

For our final demo, we realized the memory writes when the machine powered up on init were not all being written cause the memory card takes awhile to boot. Even after adding a delay in the cpu to get it to write to memory later the first instructions, this didn't help. So part of our powering on sequence is taking out and reinserting the cpu card while the computer is powered so that the init instructions are correctly written. We will need to fix this later. Otherwise, our demo showing us running, stepping though, stopping, and reseting the machine's porgram with the buttons and then the address and data leds showing the operations on the front panel worked!

Next steps for spark challenge would be to fix that error, implement deposit, examine and protect, and have a test program ready to show the full functionality of our cpu emulator. Also we need to finish the PCBs or our other 3 computers and make sure those work too.

Thank you!

## Entry 5

10pm-3 am

4/24 Thurs

5 hours

I come back from dinner and brian has the debug cables done. i hook up the front panel to our backplane with 2 cards in and monitor if the bus reads and writes address and data are showing up correctly on the LEDs. They are

then i combine the bus tables together

Function	Type	Front (12)	Description	Ownership	Panel GPIO	Card GPIO
CLK	Control		Bus clock	Panel	24	0
~PRESET	Control		Reset	Panel	29	3
PANEL	UI		Front panel data control	Panel	27	1
PROT	UI	Front	Memory protection	Panel	15	47
M1	Status	Front	First machine cycle of instruction	CPU		
HLTA	Status	Front	Halt	CPU	0	36
STACK	Status	Front	Stack operation	CPU	1	37
~PHOLD	DMA		Hold bus control			
DBIN	R/W		Data bus in	CPU	25	7
WO	R/W	Front	Write-out	CPU	2	38
WAIT	R/W	Front	Memory/IO wait	CPU	13	40
PRDY	I/O		IO ready		46	2
OUT	I/O	Front	Output IO cycle	CPU	9	32
INP	I/O	Front	Input IO cycle	CPU	5	35
XRDY	Memory		Memory ready	RAM	47	4
MWRT	Memory		Memory write strobe	CPU, Panel	26	6
MEMR	Memory	Front	Memory read strobe	CPU, Panel	6	34
INT	Interrupt	Front	Interrupt request		44	39
INTA	Interrupt		Interrupt acknowledge	CPU	28	5
INTE	Interrupt	Front	Interrupt enable	CPU	14	46
HLDA	Status	Front	Hold acknowledge		11	41
M1	Status		First machine cycle		8	33
A0	Address		Address line		31	16
A1	Address		Address line		41	17
A2	Address		Address line		33	18
A3	Address		Address line		35	19
A4	Address		Address line		16	20
A5	Address		Address line		18	21
A6	Address		Address line		22	22
A7	Address		Address line		20	23
A8	Address		Address line		42	24
A9	Address		Address line		43	25
A10	Address		Address line		45	26
A11	Address		Address line		3	27
A12	Address		Address line		12	28
A13	Address		Address line		10	29
A14	Address		Address line		7	30
A15	Address		Address line		4	31
D0	Data		Tri-state data	CPU, RAM, Panel	40	8
D1	Data		Tri-state data	CPU, RAM.	30	9

Then i work on figuring out how the front panel will interact with the bus and how start and stop will work. I determine that stop will stop the clock and use the halt signal in some way.

caleb gets back and he takes over implementing the front panel.

I then switch to integrating the bus read and write from cpu into the cpu emulator. we're not going with making a new file as i did earlier or making 2 separate packages. Instead, the emulator package right now I will just copy the cpu embassy read write code into for reading and writing.

I did this, however, if I want singular read and write functions, I'm going to have to pass in the interaction to the pio state machines and that involves borrowing and lifetimes. I don't know how to do that really yet so I'm waiting for brian to do his bus signal checking program, and then finish fixing the bus

## Entry 4

2pm - 9 pm

4/25 Thursday

7 hours

ok figured out issue pin 34 not being able to be read as that's part of the read/write sequence.

it's that there's a 16 pin offset and the gpiobase must be selected. so you do pin 18 instead of 34 and it works.

ok now that I knew it works, i fixed the read code in pio-recall to respond to smemr changes and it worked.

now that that worked i'm going to try integrating writes again. i made a new set of files called pio-cycle3 and pio-recall3 that will be the newest version to test reads and writes running at the same time

I copied pio-cycle and pio-recall to them and then added changes from pio-recall2 to the memory. I tested with the write state machine operating at the same time and reads worked. shown below

```

pio-recall.rs
115 async fn main(_spanner: Spanner) {
173   loop {
186     info!("Memory read request: address 0x{:08X}", address);
187
188     // Look up the data at this address
189     let data: u8 = memory[address as usize];
190     info!("Returning data: 0x{:02X}", data);
191
192     // Push the data to the data control SM
193     sm1.tx().wait_push(data as u32).await;
194     irq2.wait().await; // wait for transaction to be done
195
196     // pio1.sm0.tx().push(0); // push to smemr control to let it k
197     // print tx level
198     let level = sm1.tx().level();
199     info!("tx level = {:02x}", level);
200
201     // info!("data pushed to data control");
202   }
203 }
204
205 // Create a test memory array with some predefined values
206 fn create_test_memory() -> [u8; MEMORY_SIZE] {
207   let mut memory: [u8; ] = [0u8; MEMORY_SIZE];
208
209   // Pattern for easy visual identification of address
210   for i: usize in 0..MEMORY_SIZE {
211     memory[i] = (i & 0xff) as u8;
212   }
213
214   // Special values for our test addresses
215   memory[0x0000] = 0xAA; // Address 0x0000 -> 0xAA
216   memory[0x2008] = 0x5A; // Address 0x2008 -> 0x5A (as in
217   memory[0x3000] = 0x33; // Address 0x3000 -> 0x33
218   memory[0x4000] = 0x44; // Address 0x4000 -> 0x44
219   memory[0xFFFF] = 0xFF; // Highest address -> 0xFF
220
221   memory
222 }

pio-recall3.rs
164 async fn main(_spanner: Spanner) {
230   // reads
231   if !pio1.sm0.rx().empty() { // if smemr
232     pio1.sm0.rx().wait_pull().await; // pull irq off stack
233
234     sm1.tx().wait_push(0).await;
235     let address: u32 = sm1.rx().wait_pull().await as u32;
236     // info!("received");
237     // // print rx level
238     let level = sm1.rx().level();
239     info!("rx level = {:02x}", level);
240
241     // Log the memory access
242     info!("Memory read request: address 0x{:08X}", address);
243
244     // Look up the data at this address
245     let data: u8 = memory[address as usize];
246     info!("Returning data: 0x{:02X}", data);
247
248     // Push the data to the data control SM
249     sm1.tx().wait_push(data as u32).await;
250     irq2.wait().await; // wait for transaction to be done
251
252     // pio1.sm0.tx().push(0); // push to smemr control to let it k
253     // print tx level
254     let level = sm1.tx().level();
255     info!("tx level = {:02x}", level);
256
257     // info!("data pushed to data control");
258
259   // writes
260   if !sm0.rx().empty() {
261     let write: u32 = sm0.rx().wait_pull().await as u32;
262
263     // split the address and data
264     let address: usize = (write >> 8) as usize; // Address is in t
265     let data: u8 = (write & 0xff) as u8; // Data is in the lower 8
266
267     // Log the memory write access
268     info!("Memory write request: address 0x{:08X}, data 0x{:02X}",
269
terminal
pio cycle: embassy_main_task:([async_fnm0] @ cycle/src/bin/pio-cycle.rs:185
18-394736 INFO Initiating read from address 0x00002008
pio cycle: embassy_main_task:([async_fnm0] @ cycle/src/bin/pio-cycle.rs:175
18-397600 INFO Read data 0x00 from address 0x00002008
pio cycle: embassy_main_task:([async_fnm0] @ cycle/src/bin/pio-cycle.rs:185
22-398054 INFO Initiating read from address 0x00003000
pio cycle: embassy_main_task:([async_fnm0] @ cycle/src/bin/pio-cycle.rs:175
22-401001 INFO Read data 0x23 from address 0x00003000
pio cycle: embassy_main_task:([async_fnm0] @ cycle/src/bin/pio-cycle.rs:185
26-401386 INFO Initiating read from address 0x00004000
pio cycle: embassy_main_task:([async_fnm0] @ cycle/src/bin/pio-cycle.rs:175
26-404143 INFO Read data 0x44 from address 0x00004000
pio cycle: embassy_main_task:([async_fnm0] @ cycle/src/bin/pio-cycle.rs:185
rs:246
16.079738 INFO Memory read request: address 0x00002008
pio-recall3: embassy_main_task:([async_fnm0] @ recall/src/bin/pio-recall3.rs:242
16.079898 INFO Returning data: 0x00
pio-recall3: embassy_main_task:([async_fnm0] @ recall/src/bin/pio-recall3.rs:246
20.083063 INFO Memory read request: address 0x00003000
pio-recall3: embassy_main_task:([async_fnm0] @ recall/src/bin/pio-recall3.rs:242
20.083224 INFO Returning data: 0x33
pio-recall3: embassy_main_task:([async_fnm0] @ recall/src/bin/pio-recall3.rs:246

```

ok i now know how setting pinsdirs works.  
 got writes to work and read addr is setting good.  
 now just need to fix data returned on reads.  
 i'm setting up the oscilloscope to read all the data lines

ok oscilloscope didn't help that much but commenting out the cpu to see that the recall was still driving the lines made it clear recall was the issue  
 after changing the pindirs for the recall to only turn on when needed, i fixed it.  
 here are final reads and writes working:



```
async fn main(spawner: Spawner) {
    let data_pins: [&Pin<'_, PIO0>] = &data_addr_pins[0..8];

    // Setup pin for SPIRRA control and xrdy
    let smemr_pin: &Pin<'_, PIO1> = &pio1.common.make_pin(p.PIN_34);
    common.make_pin(p.PIN_4); // xrdy pin (input, active high)
    let murt_pin: &Pin<'_, PIO0> = &common.make_pin(p.PIN_6); // active low

    // Configure PIO state machines
    setup_smemr(&mut pio1.common, &mut pio1.sm0, smemr_pin);
    setup_reads(&mut common, &mut sm1, &addr_pins, &data_pins);

    setup_writes(&mut common, &mut sm2, &data_addr_pins, murt_pin);

    // Enable state machines
    pio1.sm0.set_enable(true);
    sm1.set_enable(true);
    sm2.set_enable(true); // write machine

    // Define test addresses and data for our read/write operations
    let test_addresses: [u32; 4] = [
        0x2000, // Address 0x2000 (as shown in timing diagram)
        0x3000, // Another test address
        0x4000, // Another test address
        0xFFFF, // Highest possible address
    ];
    let test_data: [i32; 4] = [
        0x27, // Test data
        0x31, // Test data
        0x41, // Test data
        0xF1, // Test data
    ];

    let mut current_address: usize = 0;

    189
    async fn main(spawner: Spawner) {
    242
        info!("Memory simulator ready");
    243
    244
        loop {
    245
            // reads
    246
            if !pio1.sm0.rx().empty() { // if smemr
    247
                pio1.sm0.rx().wait_pull().await; // pop notification
    248
                sm1.tx().wait_push(0).await; // notify state machine to start read
    249
                // set the data to output
    250
                sm1.tx().wait_push(0xFF).await;
    251
            }
    252
            // set the data to input
    253
            let address: u32 = sm1.rx().wait_pull().await as u32;
    254
            // info!("received");
    255
            // print rx level
    256
            // let level = sm1.rx().level();
    257
            // info!("rx level = {:02x}", level);
    258
            // Log the memory access
    259
            info!("Memory read request: address 0x{:08x}", address);
    260
            // Look up the data at this address
    261
            let data: u8 = memory[address as usize];
    262
            info!("Returning data: 0x{:02x}", data);
    263
            // Push the data to the data control SM
    264
            sm1.tx().wait_push(data as u32).await;
    265
            irq2.wait().await; // wait for transaction to be done
    266
            // set the data to input
    267
            sm1.tx().wait_push(0x00).await;
    268
        }
    269
    270
    271
    272
    273
    274
    275
    276
    277
}

pio_cycle3:: embassy_main_task::(async_fn#0) @ cycle\src\bin\pio-cycle3.rs:255
427486 INFO Initiating write of 0x01 to address 0x00004000
pio_cycle3:: embassy_main_task::(async_fn#0) @ cycle\src\bin\pio-cycle3.rs:269
430261 INFO Write complete to address 0x00004000
pio_cycle3:: embassy_main_task::(async_fn#0) @ cycle\src\bin\pio-cycle3.rs:278
430592 INFO Initiating read from address 0x0000FFFF
pio_cycle3:: embassy_main_task::(async_fn#0) @ cycle\src\bin\pio-cycle3.rs:242
434350 INFO Read data 0xFF from address 0x0000FFFF
pio_cycle3:: embassy_main_task::(async_fn#0) @ cycle\src\bin\pio-cycle3.rs:255
434783 INFO Initiating write of 0xF1 to address 0x0000FFFF
pio_cycle3:: embassy_main_task::(async_fn#0) @ cycle\src\bin\pio-cycle3.rs:269
437393 INFO Write complete to address 0x0000FFFF
pio_cycle3:: embassy_main_task::(async_fn#0) @ cycle\src\bin\pio-cycle3.rs:278
C:\Users\jayan\Documents\2\8800\rs>

pio_recall3:: embassy_main_task::(async_fn#0) @ recall\src\bin\pio-recall3.rs:268
40.352638 INFO Memory write request: address 0x0000, data 0x01
pio_recall3:: embassy_main_task::(async_fn#0) @ recall\src\bin\pio-recall3.rs:302
40.352834 INFO Memory updated
pio_recall3:: embassy_main_task::(async_fn#0) @ recall\src\bin\pio-recall3.rs:306
48.355635 INFO Memory read request: address 0x0000FFFF
pio_recall3:: embassy_main_task::(async_fn#0) @ recall\src\bin\pio-recall3.rs:264
48.355793 INFO Returning data: 0xFF
pio_recall3:: embassy_main_task::(async_fn#0) @ recall\src\bin\pio-recall3.rs:268
56.359927 INFO Memory write request: address 0xFFFF, data 0xF1
pio_recall3:: embassy_main_task::(async_fn#0) @ recall\src\bin\pio-recall3.rs:302
56.360143 INFO Memory updated
pio_recall3:: embassy_main_task::(async_fn#0) @ recall\src\bin\pio-recall3.rs:306
PS C:\Users\jayan\Documents\2\8800\rs>
```

now that it was good i needed to integrate the cpu emulator

i gave the code to claude and the emulator code and toolkit to make a new file that used both it came up with one



then i programmed the mem card. the mem card was spamming returns.

the i switched to helping caleb setup dev board board as a deug probe  
and the other as a micro

he programmed his cpu code on it successfully. so now we can show that a cpu works

we tried the code but all the pins were showing zero

then I remembered that the pull up resistors exist. we needed to turn them on in order for the signals to be read.

ok the reason the original bus reads wrked even when each pio block can only read from 32 pins is that the pin it was writing and reading from "34" was the same, just not actually 34.

they really can only read from 32 pins at once

i'm stuck

a square wave on pin 34 is not being picked up.

## Entry 2

3:45pm-5pm

Tuesday 4/22

1.25 hours

Okay need to fix writes

Tested reads but they didn't work

looks like i forgot to initialize the pin as a pio pin on the cpu card

tied the oscilloscope up to the breakout pins brian made and it worked

now needed to get writes and reads working at the same time

tested reads individually and those worked. tested writes individually and those worked. but together they didn't.

ok i actually found the problem. on the ram side, if

`setup_mem_write_control(&mut common, &mut sm1, &data_addr_pins, xrdy_pin);`

is enabled, then the cpu doesn't get the correct data returned to it on reads, but when it's disabled, it does. why is this so?

Chatgpt response:

This happens because **both state machines (sm0 and sm1) on the RAM side are configured to control the same pins** (the data pins and address pins), but with different directions and purposes:

- `sm0` (read SM) sets the data pins as outputs (to drive data to the CPU during a read).

- **sm1** (write SM) sets the data pins as inputs (to receive data from the CPU during a write).

### When both are enabled at the same time:

- According to the RP2040 PIO docs, for each pin, the highest-numbered enabled state machine (here, sm1) controls the output level and direction.
- So, even during a read, sm1 is setting the data pins as inputs, overriding sm0's attempt to drive them as outputs.
- As a result, the RAM cannot drive the data bus during a read, and the CPU sees zeros or floating values.

## Entry 1

7:15pm-3am

4/21 Mon

7.75 hours

Ok pio time.

going to rerun hi to show brian the not detecting high pin problem. then we'll look at the gpio registers

The screenshot shows a Rust IDE with two files open. The left file, `src/bin/hi.rs`, contains the main logic for setting up the PIO state machines. It defines a `PIO_IRQ_0` interrupt handler, configures a clock generator, and sets up two state machines: `sm0` for generating clock pulses and `sm1` for detecting rising edges. The right file, `src/bin/hi.rs`, shows the `main` function where the PIO is initialized, pins are configured, and the state machines are loaded with programs. The terminal at the bottom displays debug logs from the `embassy_executor::main` task, showing a sequence of clock pulses being received by `sm2` (labeled as `embassy_main_task` in the logs).

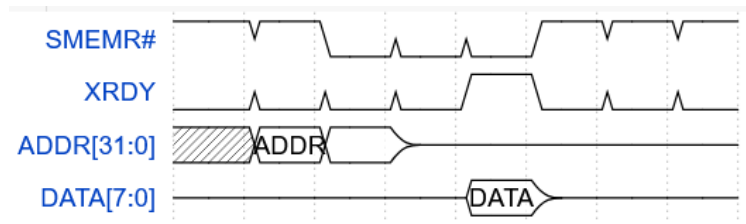
```

15 bind_interrupts!(struct irqs {
16     PIO_IRQ_0 => PioInterruptHandler<PIO0>;
17 });
18
19 /// Configure PIO for generating continuous clock pulses
20 fn setup_clock_generator<'a>() {
21     let mut common = PIO0;
22     let mut state_machine = PIO0, SM: 0;
23     let clk_pin = &Pinc'a, PIO0;
24 }
25
26 /// PIO program for generating continuous clock pulses
27 // This program toggles the output pin at a fixed rate
28 let prg: ProgramWithDefines<ExpandedDefines, _> = pio_asm!(
29     "set pins, 1 [30]"
30     ".wrap_target",
31     "pull block",
32     "set pins, 0 [30]", // PIN 4
33     "wait 0 gpio 30",
34     "set pins, 1 [30]", // PIN 4
35     ".wrap",
36 );
37
38 // Configure the state machine
39 let mut cfg: Config<'_, PIO0> = PioConfig::default();
40 cfg.use_program(prg);
41
42 // Configure pins
43 cfg.set_set_pins(&clk_pin);
44
45 // Set CLK pin as output
46 sm.set_config(&cfg);
47
48 // Set CLK pin as output
49 sm.set_pin_dir(dir: embassy_rp::pio::Direction::Out, pins: &clk_pin);
50 } fn setup_clock_generator
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```

Ok i thought that you would need to set a pin you're using in a wait statement as a "input" pin and an "in" pin however I think you just need to select it for pio usage using `&common.make_pio_pin(p.PIN_30)`

ok my bus reads weren't working and things were getting stuck



but i realized my feed in and out direction was wrong so i fixed those

```

98  async fn main( _spawner: Spawner) {
150      let test_addresses: [i32; 4] = [
151          0x00000000,
152          0x00000001,
153          0x00000002,
154          0x00000003
155      ];
156
157      let mut current_address: u32 = 0;
158
159      info!("Starting CPU read transaction loop");
160
161      loop {
162          // Get the next address to read
163          let address: i32 = test_addresses[current_address];
164          current_address = (current_address + 1) % test_addresses.len();
165          // Start a new read transaction
166          info!("Initiating read from address 0x{:08x}", address);
167          // print tx level
168          // let level = sm1.tx().level();
169          // info!("tx level = {:02x}", level);
170
171          // Push address to address/data state machine
172          sm1.tx().wait_push(address as u32).await;
173          // info!("sent data");
174
175          // Read the data received
176          let data: u32 = sm1.rx().wait_pull().await as u32;
177          info!("Read data 0x{:02x} from address 0x{:08x}", data, address);
178          // print rx level
179          // let level = sm1.rx().level();
180          // info!("rx level = {:02x}", level);
181
182          // Wait before next transaction
183          Timer::after_millis(1000).await;
184      }
185  }
186  } fn main

```

```

89  async fn main( _spawner: Spawner) {
130      // Enable state machines
131      sm1.set_enable(true);
132
133      info!("Memory simulator ready");
134
135      loop {
136          // info!("Waiting for memory access request...");
137          // Wait for address monitor to receive an address
138          let address: u32 = sm1.rx().wait_pull().await as u32;
139          // info!("received");
140          // print rx level
141          // let level = sm1.rx().level();
142          // info!("rx level = {:02x}", level);
143
144          // Log the memory access
145          info!("Memory read request: address 0x{:08x}", address);
146
147          // Look up the data at this address
148          let data: u8 = memory[address as usize];
149          info!("Returning data: 0x{:02x}", data);
150
151          // Push the data to the data control SM
152          sm1.tx().wait_push(data as u32).await;
153          // print tx level
154          // let level = sm1.tx().level();
155          // info!("tx level = {:02x}", level);
156          // info!("Data pushed to data control");
157      }
158  }
159  } fn main
160
161  /// Create a test memory array with some predefined values
162  fn create_test_memory() -> [u8; MEMORY_SIZE] {
163      let mut memory: [u8; _] = [0u8; MEMORY_SIZE];
164
165      // Pattern for easy visual identification of address
166      for i in 0..MEMORY_SIZE {

```

So it works!

Next i changed the pins to the actual ones that will be used by the bus so we can see the correct address and data pins lighting up.

When I compiled and ran it, the cycle half didn't work cause smemr is pin 34 which is outside of 0-31 so it can't set gpiobase at the same time. this didn't happen with the ram side since the control pin that ram need to drive (xrdy) is pin 4 and that is within the range.

I just used chatgpt to split up the state machine into 2 with 1 just dedicated to driving smemr and it worked.

## Week 14

OK FINALLY THE FINAL PUSH

### Entry 5

9:45-10:15

Weds 4/16

9.5 hours

Brian had completed a new front panel in the afternoon and i needed to test if it worked

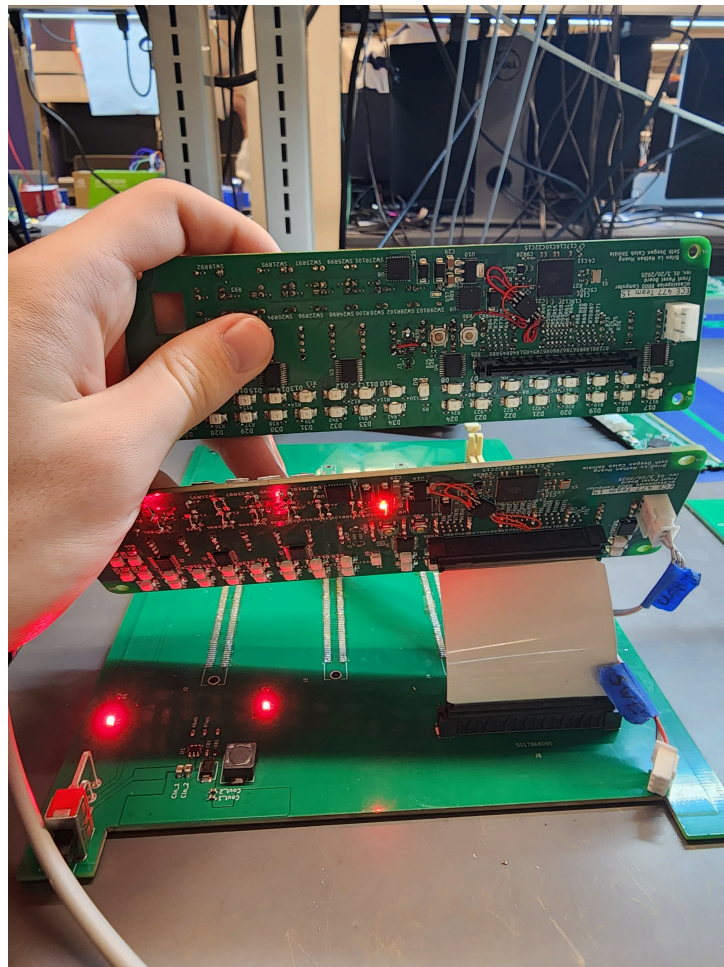
i programmed it with a lightup all program to lightup all the leds

none of the leds lit up

i then tried reprogramming the original back panel just to make sure the program works that i flashed. it worked

i then plugged in the new one again and reflashed but it still did not work

i noticed that some of the flash chip reworked connections brian made on the original front panel were not present on the new one. you can see below where the new one is the bottom one.



I think some of the connections have to deal with sending data over. I ran

```
probe-rs verify target\thumbv8m.main-none-eabihf\debug\lightup
```

Verification failed

The verification failed because it can't actually read from the flash chip. it thinks it wrote but the read/write lines are not fully connected. Brian will need to come in and add these.

okay so i don't have a good final pcb to work with so going to switch back to working with the dev board  
I need to figure out why waiting is not working.

ok brian came in and we fixed swd

had issues programming

one pico doesn't work

then fixed buttons

and all leds on new front panel

still cannot get new bus to work but trying things like only setting one pin

now going to do watchdog to full reset controller. added that to vscode debug. we can always use reset button to full reset

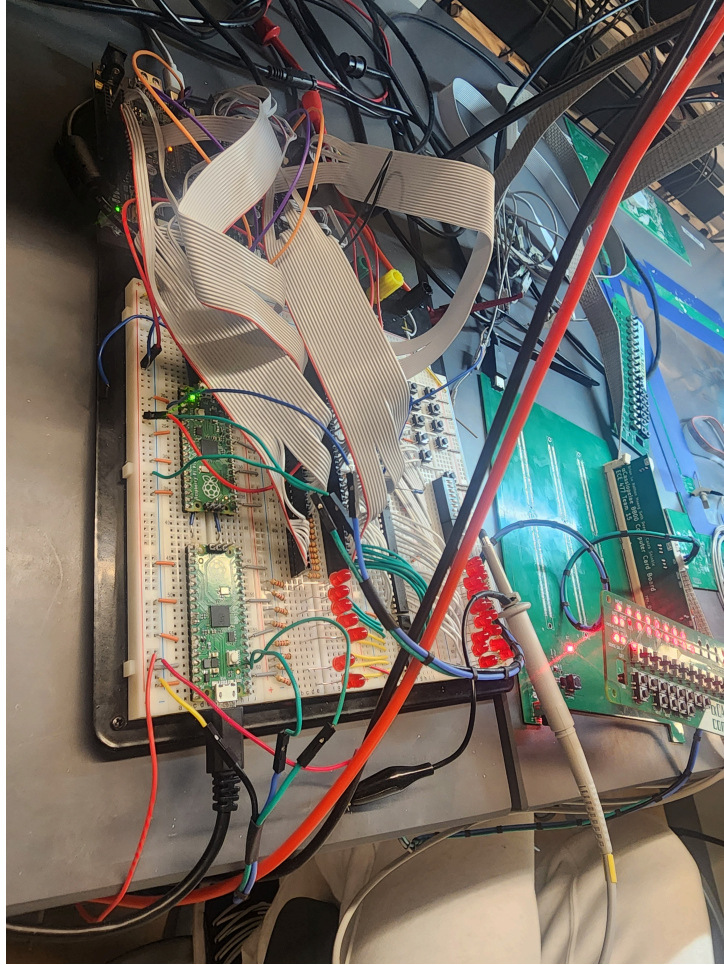
we then ran interchange which was reading from i2c to see if the buttons now work! they do. just needed to fix one button.

```
46.446450 INFO data = 00 00 ff 1f
└─ interchange::__embassy_main_task::{async_fn#0} @ interchange\src\bin\interchange.rs:161
46.500069 INFO data = 00 00 ff 9f
└─ interchange::__embassy_main_task::{async_fn#0} @ interchange\src\bin\interchange.rs:161
46.553667 INFO data = 00 00 ff 9f
└─ interchange::__embassy_main_task::{async_fn#0} @ interchange\src\bin\interchange.rs:161
46.607296 INFO data = 00 00 ff bf
└─ interchange::__embassy_main_task::{async_fn#0} @ interchange\src\bin\interchange.rs:161
46.660916 INFO data = 00 00 ff bf
```

Ok next we wanted to get the card working so we could program the card and front panel at the same time and use them for bus transfer wrtiting. we needed another swd cable for the card to be able to program them both at once so brian made one

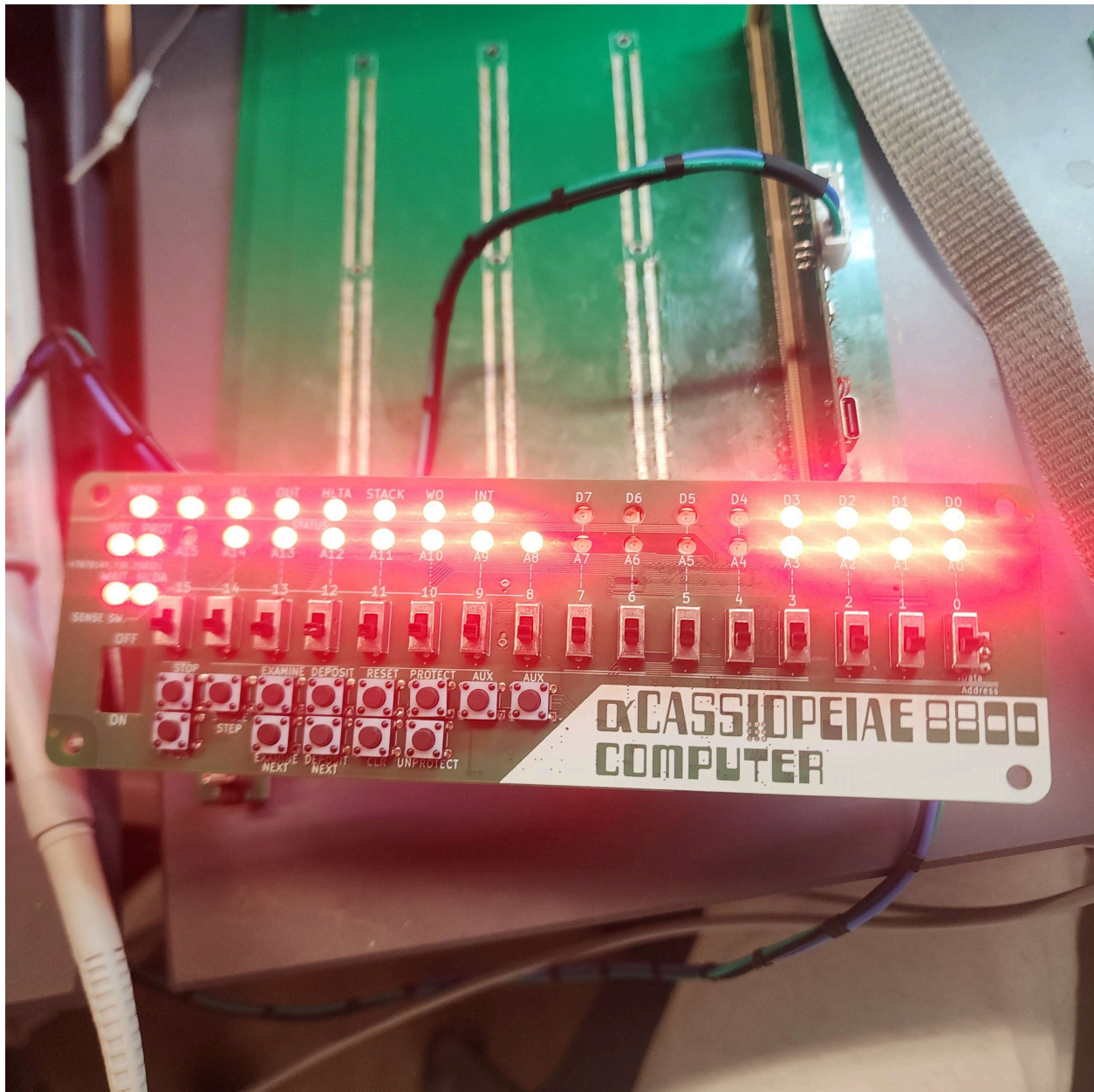
I then used the picos on the board as debug probes since the other pico didn't work and wired them up to the card and front panel. it looks like this (green and blue silicone wires):





We then programmed the card. it flashed but the program wasn't running. there weren't any outputs to console. Brian and i setup openocd debugging and noticed it was hard faulting somewhere. We didn't see anything wrong with the code cause it worked on another board. so we realized it was a hardware problem. brian noticed the chip select was not soldered well, fixed that, brought it back, and the program ran as intended. we just set all the pins to high from the card and this should trigger all the leds on the front panel as they are tied to the bus too. we noticed that they did not all turn on:





Because they did not all turn on that means not all of the connections were good between the front panel and card. so brian went to inspect and fix these.

Brian fixed all of them but A11 and HLDA. Then those were fixed and everything lit up.

Then we needed to verify all the control lines that were not the leds had connections between the card and front panel. i setup a front panel program to set all the gpios to inputs except the i2c lines and had it printed al the ones that were high. they were all high!

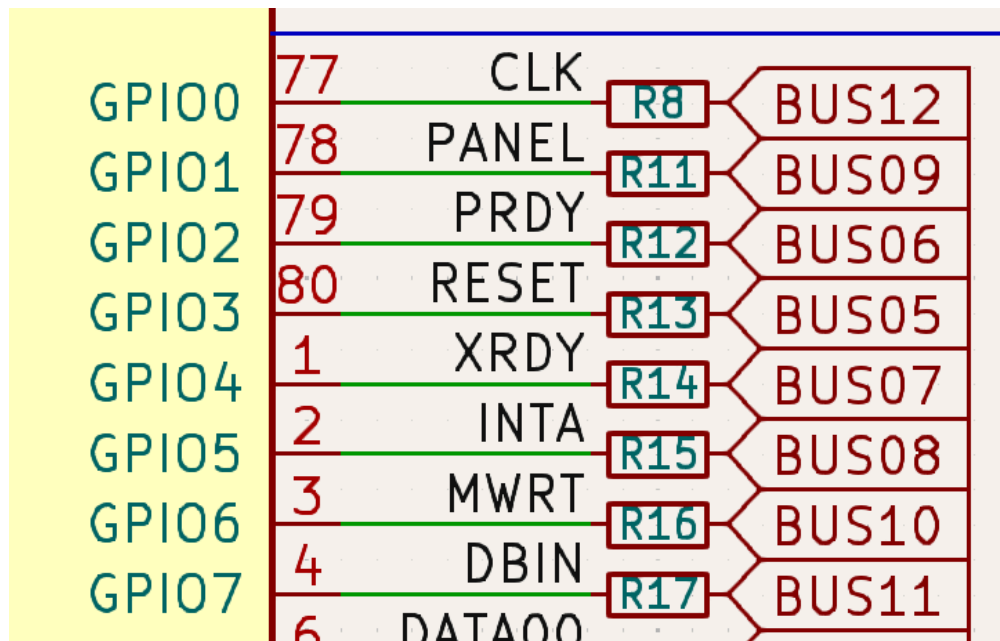
```

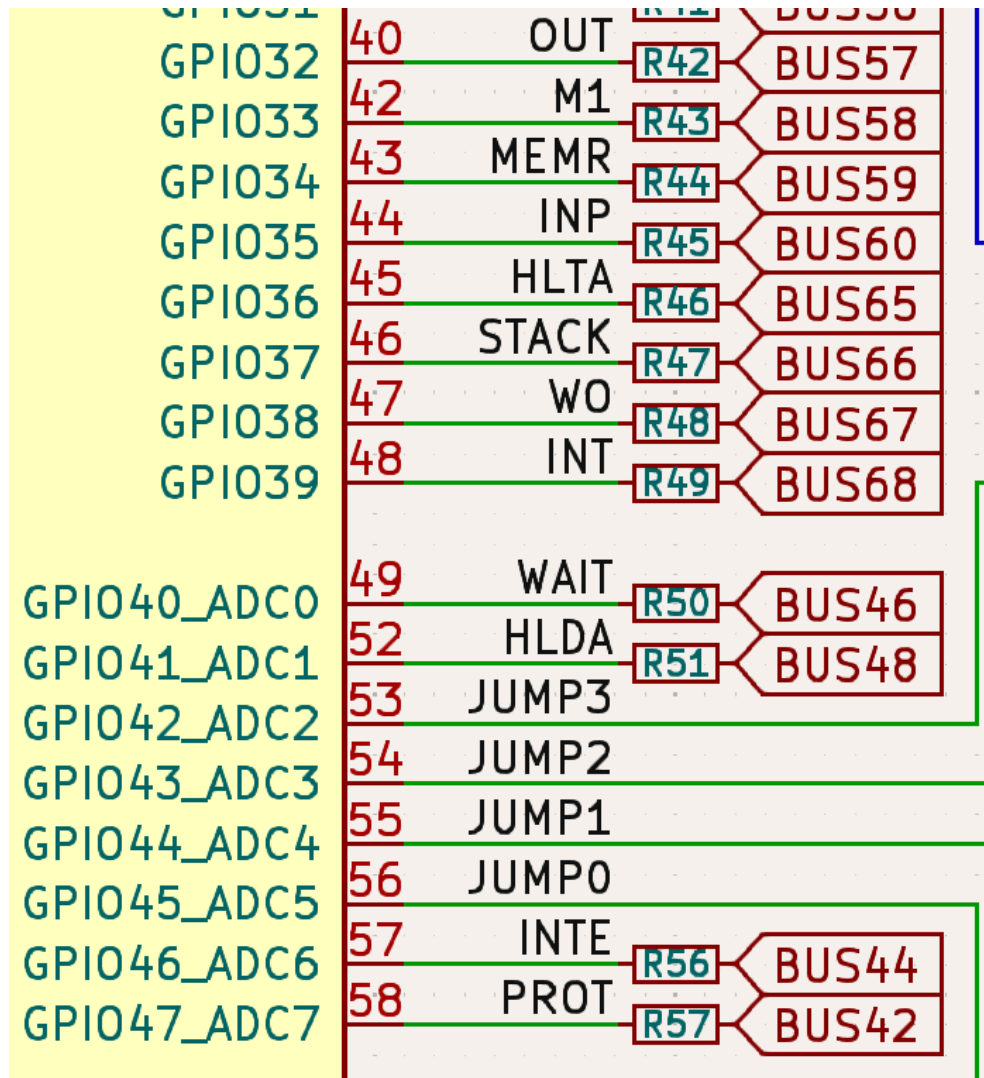
└ inputs::____embassy_main_task::{async_fn#0} @ interchange\src\bin\inputs.rs:105
1.633343 INFO led at index 17 is low
└ inputs::____embassy_main_task::{async_fn#0} @ interchange\src\bin\inputs.rs:105
1.633450 INFO led at index 18 is low
└ inputs::____embassy_main_task::{async_fn#0} @ interchange\src\bin\inputs.rs:105
1.633553 INFO led at index 19 is low
└ inputs::____embassy_main_task::{async_fn#0} @ interchange\src\bin\inputs.rs:105
1.633659 INFO led at index 20 is low
└ inputs::____embassy_main_task::{async_fn#0} @ interchange\src\bin\inputs.rs:105
1.633766 INFO led at index 21 is low
└ inputs::____embassy_main_task::{async_fn#0} @ interchange\src\bin\inputs.rs:105
1.633870 INFO led at index 22 is low
└ inputs::____embassy_main_task::{async_fn#0} @ interchange\src\bin\inputs.rs:105
1.633974 INFO led at index 23 is low
└ inputs::____embassy_main_task::{async_fn#0} @ interchange\src\bin\inputs.rs:105
1.634083 INFO led at index 24 is low
└ inputs::____embassy_main_task::{async_fn#0} @ interchange\src\bin\inputs.rs:105
1.634188 INFO led at index 25 is low
└ inputs::____embassy_main_task::{async_fn#0} @ interchange\src\bin\inputs.rs:105
1.634293 INFO led at index 26 is low
└ inputs::____embassy_main_task::{async_fn#0} @ interchange\src\bin\inputs.rs:105
1.634400 INFO led at index 27 is low
└ inputs::____embassy_main_task::{async_fn#0} @ interchange\src\bin\inputs.rs:105
1.634504 INFO led at index 28 is low
└ inputs::____embassy_main_task::{async_fn#0} @ interchange\src\bin\inputs.rs:105
1.634614 INFO led at index 29 is low
└ inputs::____embassy_main_task::{async_fn#0} @ interchange\src\bin\inputs.rs:105
1.634720 INFO led at index 30 is low
└ inputs::____embassy_main_task::{async_fn#0} @ interchange\src\bin\inputs.rs:105
1.634822 INFO led at index 31 is low
└ inputs::____embassy_main_task::{async_fn#0} @ interchange\src\bin\inputs.rs:105
1.634931 INFO led at index 32 is low
└ inputs::____embassy_main_task::{async_fn#0} @ interchange\src\bin\inputs.rs:105
1.635036 INFO led at index 33 is low
└ inputs::____embassy_main_task::{async_fn#0} @ interchange\src\bin\inputs.rs:105
1.635141 INFO led at index 34 is low
└ inputs::____embassy_main_task::{async_fn#0} @ interchange\src\bin\inputs.rs:105
1.635245 INFO led at index 35 is low
└ inputs::____embassy_main_task::{async_fn#0} @ interchange\src\bin\inputs.rs:105
1.635351 INFO led at index 36 is low
└ inputs::____embassy_main_task::{async_fn#0} @ interchange\src\bin\inputs.rs:105
1.635458 INFO led at index 37 is low
└ inputs::____embassy_main_task::{async_fn#0} @ interchange\src\bin\inputs.rs:105
1.635568 INFO led at index 38 is low
└ inputs::____embassy_main_task::{async_fn#0} @ interchange\src\bin\inputs.rs:105

```

do now we have verified our backplane, front plane, and card connections are all good!

Ok now i can get started on actually programming with our real pcbs! I needed the bus signal notations for each gpio pin on the card. I checked the kicad schematic however the control signal lines were not notated. I fixed these





I now can use the MEMR to indicate to the memory that i would like to read.

I need to also know the mappings for the data and addr lines between the card and front panel, so i created a mapping table of those and the rest of the control signals:

Function	Panel GPIO	Card GPIO
A0	31	16
A1	41	17
A2	33	18
A3	35	19
A4	16	20
A5	18	21
A6	22	22
A7	20	23
A8	42	24
A9	43	25
A10	45	26
A11	3	27
A12	12	28
A13	10	29
A14	7	30
A15	4	31
D0	40	8
D1	30	9
D2	32	10
D3	34	11
D4	17	12
D5	19	13
D6	21	14
D7	23	15
HLDA	11	41
STACK	1	37
INTE	14	46
PROT	15	47
WAIT	13	40
INT	44	39
HLTA	0	36
WO	2	38
OUT	9	32
M1	8	33
MEMR	6	34
INP	5	35
CLK		0
PANEL		1
PRDY		2
RESET		3
XRDY		4
INTA		5
MWRT		6
DBIN		7

Next steps are to change the dev board code to work on the real pcbs with the right gpio ports and get the final read and write transaction code working.

## Entry 4

10am-11am

Wednesday 4/16

1 hour

I started with [hm.rs](#) to try to build up to a final protocol from simple to complicated

I learned that the push was working but the tx was getting full and the transactions didn't work

I also learned that even though gpio 5 is high, the wait condition was not continuing. Need to investigate the wait command more.

## Entry 3

10pm-4am

Tuesday 4/15

6 hours

Okay reread about pio. Know all the push and pulls now. I learned that irqs or just paying attention to the rx/tx fifo buffer is how you can detect signals or new data from PIO state machines

Ok now testing written code by claude

Looks like recall is always detecting a read but cycle is not receiving a response

I made a simple pio program just turning a pin on and off to make sure the control signal pins were working. that worked when i saw the signal on the oscilloscope.

Now i looked through the program again and made changes where i just constantly asserted smemr and dbin high and low to make sure they were outputting correctly. they were.

Ok through trial and error and using copilot to compare the 2 files, i learned that you need to call `set_set_pins` instead of `set_out_pins` cause i was using set instead of out to push to the pins. you also HAVE to have `"set pindirs, 1",`.

Ok i figured out it just can't register a 1 likely cause there are resistors between the bus lines. That's annoying cause that means we can only pull low for an acknowledgement. Will implement that

## Entry 2

2:00pm-4pm

Tuesday 4/15

2 hours

Okay need to figure out why all the address lines are not being driven over the bus from the card.

Triggered all GPIO pins but they didn't all light up.

Checked to make sure front panel worked with all pins again in case the gpio pins were damaged or something and they were fine.

Also check an output signal was being sent from the card to the backplane and they were for the LEDs that were missing

Now going to check the connections.

## Entry 1

Tuesday 4/15

2am-4am

2 hours

Okay right now I'm moving changes from the new-toolchain branch to the main branch so we can get debugging on it later if we want. Ok that took awhile but brian cleaned up all the packages and added docs and stuff so it works nice. The debugging may be useful.

After everything was merged, there were some rust analyzer complaints, so i just fixed those.

Okay next step is to get the switches to actually light up their individual LEDs above them instead of just arbitrary ones that were next to each other.

## Week 13

This week was spent debugging why our PIO was not working and testing our code for interchange on the final PCB for the front panel with Brian.

## Entry 4

Friday night

3 hours

10pm-1am

During the time I was away Brian setup VSCode debugging via GDB and OpenOCD so that we could figure out root case by tracing through to verify that GPIOBASE was actually set.

He did this by using the [AArch32 bare-metal target Toolchain](#) instead of the one that comes with Rust that probe-rs/openocd uses. This gave us the debugging notation for the ELF file and that we needed in order for debugging to work.

Here is a screenshot of the VSCode debugging working from Brian's computer:



```

713 impl<'d, PIO: Instance + 'd, const SM: usize> StateMachine<'d, PIO, SM> {
715     pub fn set_config(&mut self, config: &Config<'d, PIO>) {
782         let mut low_ok: bool = true;
783         let mut high_ok: bool = true;
784
785         let in_pins: Range<u8> = config.pins.in_base..config.pins.in_base + config.pins.in_count;
786         let side_pins: Range<u8> = config.pins.sideset_base..config.pins.sideset_base + config.pins.sideset_count;
787         let set_pins: Range<u8> = config.pins.set_base..config.pins.set_base + config.pins.set_count;
788         let out_pins: Range<u8> = config.pins.out_base..config.pins.out_base + config.pins.out_count;
789
790         for pin_range: Range<u8> in [in_pins, side_pins, set_pins, out_pins] {
791             for pin: u8 in pin_range {
792                 low_ok &= pin < 32;
793                 high_ok &= pin >= 16;
794             }
795         }
796
797         if !low_ok && !high_ok {
798             panic!(
799                 "All pins must either be <32 or >=16, in:{:?}-{:?}, side:{:?}",
800                 config.pins.in_base,
801                 config.pins.in_base + config.pins.in_count - 1,
802                 config.pins.sideset_base,
803                 config.pins.sideset_base + config.pins.sideset_count - 1,
804                 config.pins.set_base,
805                 config.pins.set_base + config.pins.set_count - 1,
806                 config.pins.out_base,
807                 config.pins.out_base + config.pins.out_count - 1,
808             );
809         }
810         let shift: u8 = if low_ok { 0 } else { 16 };
811
812         sm.pinctrl().write(|w: &mut SmPinctrl| {
813             w.set_sideset_count(val: config.pins.sideset_count);
814             w.set_set_count(val: config.pins.set_count);
815             w.set_out_count(val: config.pins.out_count);
816             w.set_in_base(val: config.pins.in_base.checked_sub(shift).unwrap());
817             w.set_sideset_base(val: config.pins.sideset_base.checked_sub(shift).unwrap());
818             w.set_set_base(val: config.pins.set_base.checked_sub(shift).unwrap());
819             w.set_out_base(val: config.pins.out_base.checked_sub(shift).unwrap());
820         });
821
822         PIO::PIO.gpiobase().write(|w: &mut GpioBase| w.set_gpiobase(val: shift));
823
824         if let Some(origin: u8) = config.origin {
825             unsafe { self.exec_jump(to_addr: origin) }
826         }
827     }
828 } fn set_config
829
830 /// Read current instruction address for this state machine
831 pub fn get_addr(&self) -> u8 {
832     let addr: Reg<SMAddr, RW> = Self::this_sm().addr();
833     addr.read()

```

We did this and noticed that GPIOBASE was getting set for the higher pins, unlike what we originally found. This was some erratic behavior. There was no issue it turned out in any of our packages.

We weren't sure what was the issue. I then tried to program our prototype front panel PCB with our PIO program instead of the dev boards since those seemed to be unreliable.

The program then worked for the upper pins and the LEDs lit up on the front panel!

Now that we knew the LED outputs over we then needed to verify that the I2C + IO Expanders also worked on the prototype PCBs. We need to change the pins that the microcontroller knew the IO expanders were on since they were different than our dev boards.

We then used our original program which read from I2C and then output that data on the FIFO for the state machine the PIO program was running from. This would demonstrate that flipping switches would then correspond to changed LEDs on the front panel.



```

loop {
  let mut addr0: [u8; 1] = [0];
  let mut addr1: [u8; 1] = [0];
  let mut data: [u8; 1] = [0];
  let mut tmp: [u8; 1] = [0];

  // Read from port B, top IC (data)
  i2c.write_read(address: ADDR1, write: &[GPIOA], read: &mut data).await.unwrap();

  // // Read from port B, top IC (lower addr)
  i2c.write_read(address: ADDR1, write: &[GPIOB], read: &mut addr0).await.unwrap();
  // // Read from port A, bottom IC (top addr)
  i2c.write_read(address: ADDR, write: &[GPIOA], read: &mut addr1).await.unwrap();
  i2c.write_read(address: ADDR, write: &[GPIOB], read: &mut tmp).await.unwrap();

  info!("data = {:02x} {:02x} {:02x} {:02x}", data[0], addr0[0], addr1[0], tmp[0]);

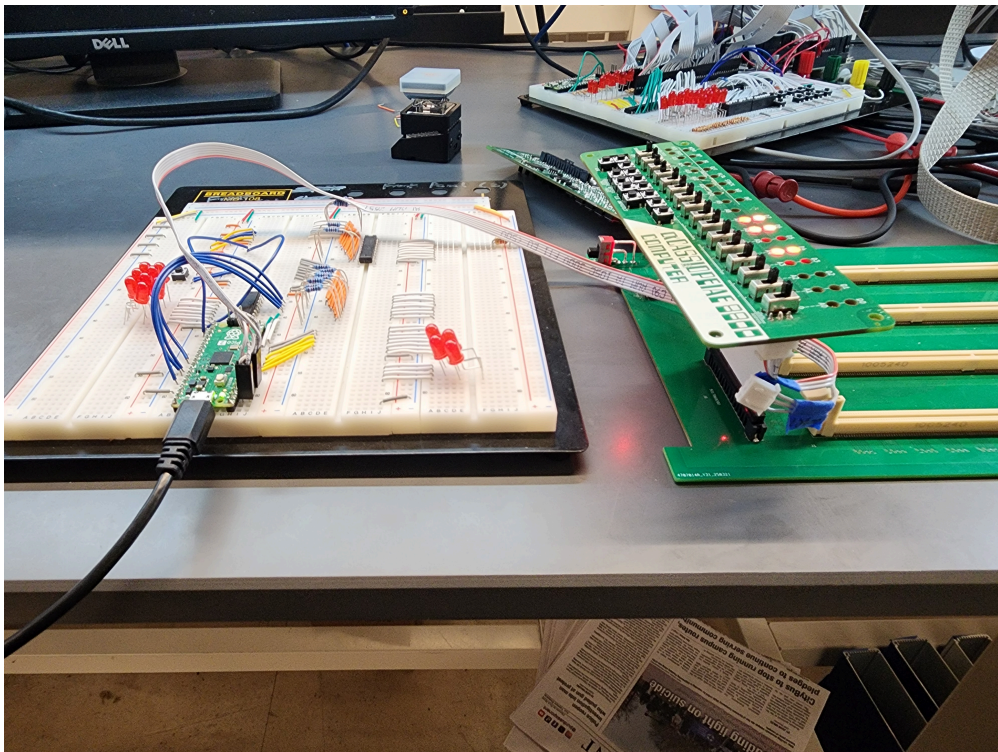
  // Send the data to the PIO FIFO - this will be output to pins 40-47
  sm0.tx().wait_push(data[0] as u32).await;

  // Optional: Add delay between updates
  Timer::after_millis(50).await;
}
main

```

And it did!

As you can see on the front panel below, 2 of the 8 switches farthest from the front of the image are flipped down while the rest are up. And likewise 6 of the 8 expected LEDs are lit up. When we flipped the other switches we saw that their corresponding LEDs switched as well. This is the expected behavior!

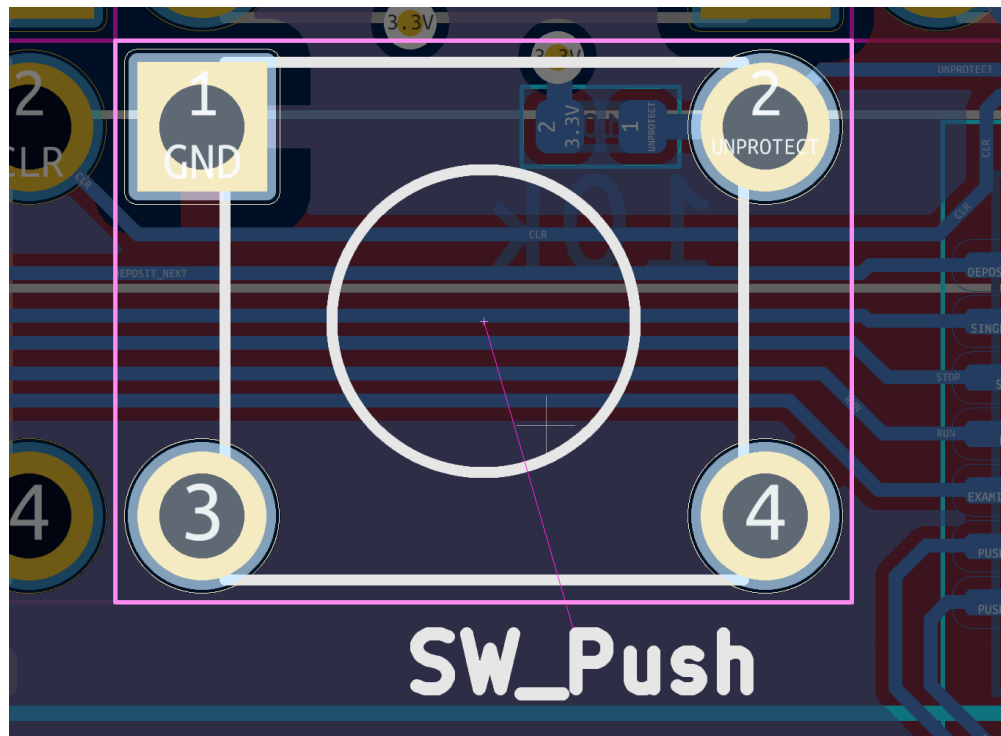


We then tested if the buttons worked as well.

We noticed that they actually did not work. When we pressed a button, no output on our terminal changed that indicated the signals coming from I2C.

When we looked at the datasheet for the button, we actually noticed that the notation in kicad for what was one side of the switch was different than the datasheet.

Below you can see that the schematic infers that when the button is pushed, pins 2 and 4 are linked with 1 and 3. But what actually happens is the button is split horizontally and pins 1 and 2 are connect to 3 and 4 when the button is pressed.



This was a annoying sign because it meant that all we were getting outputs that were just tied to ground. We realized we needed to desolder all the buttons and somehow rework them to allow for the button to actually work. We decided to later cut off pin 1 to remove it from being tied to ground.

Next steps are to actually complete the full interchange logic so that the buttons and switches work as function and bus signals are sent to control the CPU and memory from the front panel.

We also need to rework the buttons so that we can actually use them. They will need to be desoldered and legs cut off and then resoldered.

## Entry 3

4/9 Weds night

6pm-8pm

2 hours

When I came back for tonight, Brian had determined that there was a line in the `rp235x-pac` Rust crate that was not setting the GPIOBASE correctly.

I needed to apply a patch to our Cargo patch to fix this.

```
rp235x-pac patch src/inner/pio0/gpiobase.rs

impl W {
    #[doc = "Bit 4"]
    #[inline(always)]
    #[must_use]
    pub fn gpiobase(&mut self) -> GPIOBASE_W<GPIOBASE_SPEC> {
-       GPIOBASE_W::new(self, 4)
+       GPIOBASE_W::new(self, 16)
    }
}
```

Through a google search I learned there are multiple ways to do this. You can:

1. Download the repository of the package, apply the patch, and repoint your Cargo.toml to it instead of downloading it from crates-io.
2. Use a crate like [cargo-patch](#).

I decided to go with the first solution since it seemed easier and we needed to apply the patch to all of our packages in our Cargo workspace so i thought this would be easier.

I downloaded the repo and made the change and added

```
[patch.crates-io]
rp235x-pac = { path = "../rp235x-pac" }
```

to the [Cargo.toml](#) in our interchange package since that was the package we were using.

I did this and rebuilt the project. I didn't notice anything from the terminal saying that it applied the patch or anything which concerned me.

When I the programmed the project to the microcontroller with pin 47 as the output for PIO, I did not see it light up or any signal on the oscilloscope.

I was concerned the patch was not being applied. I wanted to verify that the dependency rp235x-pac was actually a dependdency since it wasn't a root-level dependency I saw in our Cargo.toml. I asked chatgpt how i could get a printout of the dependency tree with cargo and it said I should run `cargo tree`. I ran that but still did not see `rp235x-pac`.

Brian came back at this time and he also seemed to be mistaken that `rp235x-pac` was causing the problem. We decided we wanted to step through the the functions this time using a debugger instead of just searching through the code at what might be the cause for GPIOBASE not being set.

Brian and I tried GDB first, however, when we tried setting a breakpoint at a function name, it was unable to find it. We guessed that embassy or Rust mixed up or did not provide notations for the embassy functions in the ELF file cause of state machines or something so we needed to find another solution.

Brian and I decided that VSCode debugging and fixing the debugger would be the best way forward so Brian got to work at getting the debugging figured out and the VSCode launch file setup and I went home.

## Entry 2

4/9 Weds morning

10am-12am

2 hours

Today we tried to get the PIO (programmable IO) working to output to the LEDs on the dev board . We need this so that we can drive our parallel bus with PIO instead of bit banging, which is much slower.

I had tried this before on the dev board but was failing when trying to get pin 47 or 46 to trigger. I then tried a lower level pin because I thought maybe that might be the issue as some elements of the microcontroller have different operation for the larger QFN package. Pin 30 worked.

We then tested pin 46 and 47 again to make sure that the this wasn't a one off fluke. The lights on the board barely lit up for pin 30 so we verified with an oscilloscope to see if any signal could be observed. We did not see any.

We then needed to debug why some pins were working but others were not. Brian setup OpenOCD to observe the registers of the microcontroller. I installed telnet on my computer as OpenOCD requires it. We were able to observe that there was no PIO code in the registers where PIO code was supposed to be. But this was the case for both when the program specified pin 30 as the output pin and pins 46 and 47, so we didn't think this was the issue.

Brian and I then searched the datasheet for the RP2350 to see if there were any other configuration registers that controlled PIO related output and found that a GPIOBASE register exists:

### PIO: GPIOBASE Register

Offset: 0x168

Table 1016.  
GPIOBASE Register

Bits	Description	Type	Reset
31:5	Reserved.	-	-
4	Relocate GPIO 0 (from PIO's point of view) in the system GPIO numbering, to access more than 32 GPIOs from PIO.  Only the values 0 and 16 are supported (only bit 4 is writable).	RW	0x0
3:0	Reserved.	-	-

We then check that this was enabled in memory for the program that drove pins 46 and 47 but did not see this.

We then needed to search through the embassy HAL for the RP2350 to figure out if GPIOBASE was set and where.

Brian got to work on this and I went home. Next steps are to continue to debugging so that we can drive higher level GIPO pins with PIO.

## Entry 1

4/7 Monday night

10-11pm

1 hour

Today I tested that the front panel and cards were able to be programmed with Brian.

We first hooked up the card and front panel to the backplane and connected the card from a Pico acting as a debug probe to the card over SWD.

We did this after Brian last week figured out that the SWD programming was not working because the flash chip was improperly wired. Brian rewired it and we were able to reprogram it again.

We flashed a program that turned on all of the LEDs to the card

```

57     Output::new(pin: p.PIN_25, initial_output: Level::Low),
58     Output::new(pin: p.PIN_26, initial_output: Level::Low),
59     Output::new(pin: p.PIN_27, initial_output: Level::Low),
60     Output::new(pin: p.PIN_28, initial_output: Level::Low),
61     Output::new(pin: p.PIN_29, initial_output: Level::Low),
62     Output::new(pin: p.PIN_30, initial_output: Level::Low),
63     Output::new(pin: p.PIN_31, initial_output: Level::Low),
64     Output::new(pin: p.PIN_32, initial_output: Level::Low),
65     Output::new(pin: p.PIN_33, initial_output: Level::Low),
66     Output::new(pin: p.PIN_34, initial_output: Level::Low),
67     Output::new(pin: p.PIN_35, initial_output: Level::Low),
68     Output::new(pin: p.PIN_36, initial_output: Level::Low),
69     Output::new(pin: p.PIN_37, initial_output: Level::Low),
70     Output::new(pin: p.PIN_38, initial_output: Level::Low),
71     Output::new(pin: p.PIN_39, initial_output: Level::Low),
72     Output::new(pin: p.PIN_40, initial_output: Level::Low),
73     Output::new(pin: p.PIN_41, initial_output: Level::Low),
74     Output::new(pin: p.PIN_46, initial_output: Level::Low),
75     Output::new(pin: p.PIN_47, initial_output: Level::Low),
76 ];
77
78 loop {
79     info!("Lighting up all outputs...");
80     for pin: &mut Output<'_ in outputs.iter_mut() {
81         pin.set_high();
82     }
83     // Timer::after_millis(1000).await;
84
85     // info!("Turning off all outputs...");

```

PROBLEMS 12 OUTPUT DEBUG CONSOLE TERMINAL PORTS MEMORY XRTOS PLAYWRIGHT SERIAL MONITOR

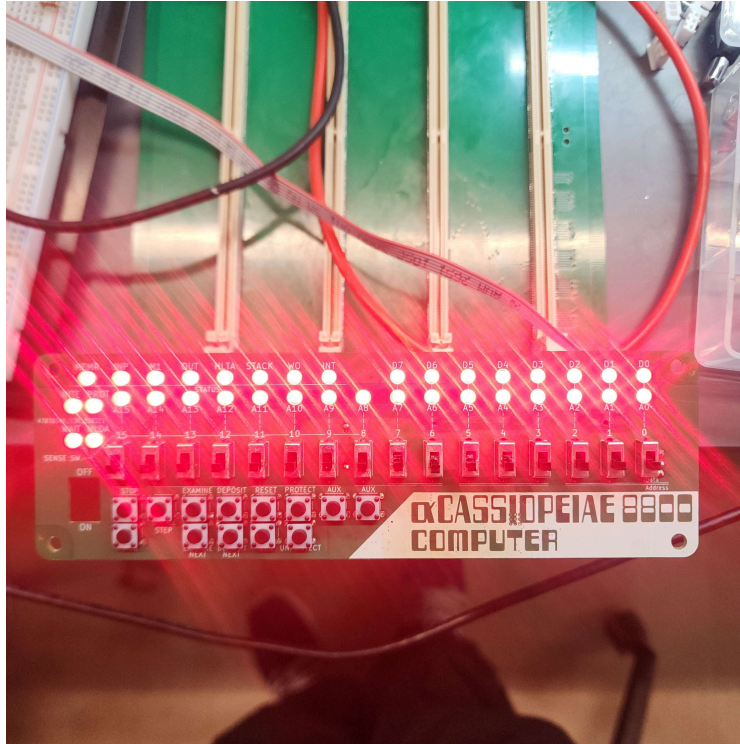
```

32.137744 INFO Lighting up all outputs...
└─ test:: embassy_main task: {async_fn#0} @ src\bin\test.rs:79
32.137951 INFO Lighting up all outputs...
└─ test:: embassy_main task: {async_fn#0} @ src\bin\test.rs:79
32.138160 INFO Lighting up all outputs...
└─ test:: embassy_main task: {async_fn#0} @ src\bin\test.rs:79
32.138364 INFO Lighting up all outputs...
└─ test:: embassy_main task: {async_fn#0} @ src\bin\test.rs:79
32.138566 INFO Lighting up all outputs...
└─ test:: embassy_main task: {async_fn#0} @ src\bin\test.rs:79
32.138769 INFO Lighting up all outputs...
└─ test:: embassy_main task: {async_fn#0} @ src\bin\test.rs:79
32.138973 INFO Lighting up all outputs...
└─ test:: embassy_main task: {async_fn#0} @ src\bin\test.rs:79
32.139182 INFO Lighting up all outputs...
└─ test:: embassy_main task: {async_fn#0} @ src\bin\test.rs:79
32.171100 INFO Lighting up all outputs...
└─ test:: embassy_main task: {async_fn#0} @ src\bin\test.rs:79
32.171402 INFO Lighting up all outputs...
└─ test:: embassy_main task: {async_fn#0} @ src\bin\test.rs:79
32.171611 INFO Lighting up all outputs...
└─ test:: embassy_main task: {async_fn#0} @ src\bin\test.rs:79

```

Almost all of the LEDs lit up on the front panel. That let us know that the connection between the card and the front panel for all the bus lines was not reliable. Our soldering for either the DIMM slot, or the ribbon cable connector may not be correct.

I then programmed the front panel with the same program and all of the LEDs did lit up this time:



This let us know that all the routings between the microcontroller on the front panel were at least correct.

Next steps are to fix the soldering between the card and the front panel so that the card can drive all the LEDs on the bus properly.

## Week 12

### Entry 1

Wednesday

10-11am

1 hour

Today I registered my team for the spark challenge and design expo. I also did a more research on how to output to parallel pins with PIO using the embassy Rust package.

## Week 11

### Entry 3

3/28 Friday

10-12

2 hours

For this time I focused on drafting the code for the rest of the front panel functionality.



I needed to write code to output to the LEDs by writing to the ADDR and Data lines on the bus.

```
// Read from port A, top IC (data)
i2c.write_read(ADDR, &[GPIOA], &mut data).await.unwrap();
info!("data = {:02x}", data[0]);

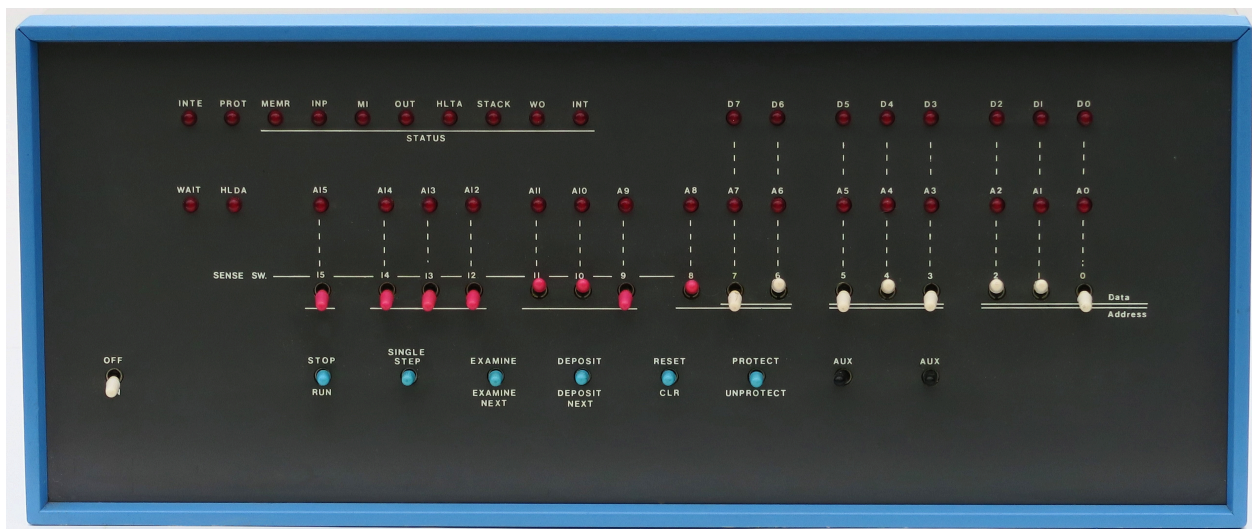
// Read from port B, top IC (lower addr)
i2c.write_read(ADDR, &[GPIOB], &mut addr0).await.unwrap();
info!("addr0 = {:02x}", addr0[0]);

// Read from port A, bottom IC (top addr)
i2c.write_read(ADDR1, &[GPIOA], &mut addr1).await.unwrap();
info!("addr1 = {:02x}", addr1[0]);
```

I need to do the button functionality and the different operations associated with them like single step, examine, and deposit.

I need to tie the switches to such programming logic.

Here is the button logic I came up with using the button reference of course below, chatgpt to remind me of each button functionality, and our bus layout table



GPIO #	Type	Name	Description	Ownership		
4	Control	CLOCK	bus clock	Panel		
5	Control	~PRESET	reset	Panel		
6	UI	PANEL	front panel data control	Panel		
7	UI	PROT	memory protection	Panel		
8	Status	SM1	first machine cycle of instruct	CPU		
9	Status	SHLTA	halt	CPU		
10	Status	SSTACK	stack operation	CPU		
11	DMA	~PHOLD	hold bus control			
12	R/W	PDBIN	data bus in	CPU		
13	R/W	SWO	write-out	CPU		
14	R/W	PWAIT	mem/io	CPU		
15	I/O	PRDY	io ready			
16	I/O	SOUT	output IO cycle	CPU		
17	I/O	SINP	input io cycle	CPU		
18	Memory	XRDY	memory ready	RAM		
19	Memory	MWRT	memory write strobe	CPU		
20	Memory	SMEMR	memory read strobe	CPU		
21	Interrupt	~PINT	interrupt request			
22	Interrupt	SINTA	interrupt acknowledge	CPU		
23	Interrupt	PINTE	interrupt enable	CPU		
24-39	Address	A{15:0}				
40-47	Data	D{7:0}	tri-state	CPU	RAM	Panel

```

if (reset) {
    nRst = 0;
    addr = 0;
}
else {
    nRst = 1;
    if (clr) {
        addr = 0;
        data = hiz;
        clock = clock;
    }
    else if (stop) {
        clock = clock;
    }
    else if (run) {
        clock = !clock;
    }
    else if (single_step) {
        single_step = 1;
    }
    else if (examine) {
        // read addr pins
        i2c.write_read(ADDR, &[GPIOB], &mut addr0).await.unwrap();
        i2c.write_read(ADDR1, &[GPIOA], &mut addr1).await.unwrap();

        // flog loan word instruction over the bus
        panel = 1;
        // send addr
        panel = 0;
    }
}

```



```

else if (examine_next) {
    // flog loan word with next addr
    panel = 1;
    panel = 0;
}
else if (deposit) {
    panel = 1;
    // read data
    i2c.write_read(ADDR, &[GPIOA], &mut data).await.unwrap();
    // send data sw (addr)
    panel = 0;
}
else if (deposit_next) {
    panel = 1;
    // read data
    i2c.write_read(ADDR, &[GPIOA], &mut data).await.unwrap();
    // send data sw addr + 1
    panel = 0;
}
}
}

```

I clarified with brian what the HALT and PANEL signals do on the bus. HALT is just a status flag for when the cpu reaches a halt instr. on the front panel we also trigger the halt led when that happens. PANEL is a flag asserted by the panel to indicate to the cpu and mem it wants to take control of the data lines. That way the panel can issue instructions to write to memory.

The next step is to turn this from psuedocode into actual rust code and write the PIO setup and runtime tasks to read and write to respective pins on the bus. I'll also need to figure out how to do reads and writes from the front panel too.

## Entry 2

3/26 Wednesday

10:00-11:00

1 hour

Today I need to fix why the messages printing to console were not always the input state of the switches.

I chatgpted this and it told me that the MCP likely cycles through using a register pointer all the registers and prints the values of those instead of just the input data to the IO expander. I would need to issue a write over I2C requesting that I wanted just the data and then it would give that back to me for each iteration.

That's when I realized that I actually needed the `write_read()` function as was used in the original I2C example. This function writes to the bus first and then reads a response. I replaced the `blocking_read()` with this line: `i2c.write_read(ADDR, &[GPIOB], &mut portb).await.unwrap();` and it worked!

```

2.513842 INFO portb = 7c
└─ interchange::__embassy_main_task::{async_fn#0} @ src\main.rs:115
3.015108 INFO portb = 7c
└─ interchange::__embassy_main_task::{async_fn#0} @ src\main.rs:115
3.516357 INFO portb = 7c
└─ interchange::__embassy_main_task::{async_fn#0} @ src\main.rs:115
4.017606 INFO portb = 7c
└─ interchange::__embassy_main_task::{async_fn#0} @ src\main.rs:115
4.518852 INFO portb = 7c
└─ interchange::__embassy_main_task::{async_fn#0} @ src\main.rs:115
5.020106 INFO portb = 7c
└─ interchange::__embassy_main_task::{async_fn#0} @ src\main.rs:115
5.521363 INFO portb = 7c
└─ interchange::__embassy_main_task::{async_fn#0} @ src\main.rs:115
6.022610 INFO portb = 7e
└─ interchange::__embassy_main_task::{async_fn#0} @ src\main.rs:115
6.523853 INFO portb = 7e
└─ interchange::__embassy_main_task::{async_fn#0} @ src\main.rs:115
7.025103 INFO portb = 7e
└─ interchange::__embassy_main_task::{async_fn#0} @ src\main.rs:115
7.526377 INFO portb = 7e

```

As you can see, it prints out in hex whether each switch is on or off and halfway here I flip one of the switches so the output turns from 7c to 7e.

I had some flashing issues before programming it because of a known bug so this took about 20 minutes to figure out how to get consistent flashing and running to occur. I figured out that hitting reset on the IC after you program it once and it doesn't run and then reprogramming it, causes it to successfully run the next time about 80% of the time. If that doesn't work after consecutive tries, unplugging and reconnecting the entire system to power over usb.

My next step was to continue working on the front panel code and

## Entry 1

3/25 Tuesday

11:30-5:30

6 hours

Today I wanted to get a working bus implementation working

I pulled out the bus prototyping board and I realized I needed debug LEDs. I could add them to the bus board, however we already had the front panel breadboard done, so I thought, oh I could just code that right now since the front panel code needs to be done at some point too.

I looked at the board and pulled up the datasheets for the 2 boards

[https://www.ti.com/lit/ds/symlink/tlc59211.pdf?](https://www.ti.com/lit/ds/symlink/tlc59211.pdf?ts=1742960394353&ref_url=https%253A%252F%252Fwww.ti.com%252Fproduct%252FTLC59211)

[ts=1742960394353&ref\\_url=https%253A%252F%252Fwww.ti.com%252Fproduct%252FTLC59211](https://www.ti.com/lit/ds/symlink/tlc59211.pdf?ts=1742960394353&ref_url=https%253A%252F%252Fwww.ti.com%252Fproduct%252FTLC59211)

<https://ww1.microchip.com/downloads/aemDocuments/documents/APID/ProductDocuments/DataSheets/MCP23017-Data-Sheet-DS20001952.pdf>

I verified all the pin connections and learned the power, data, and address pins on the io expanders

I noticed some of the ICs Nathan hadn't connected the power yet. I added the wiring for those

I then added the power and ground wires from the pico to the board rails

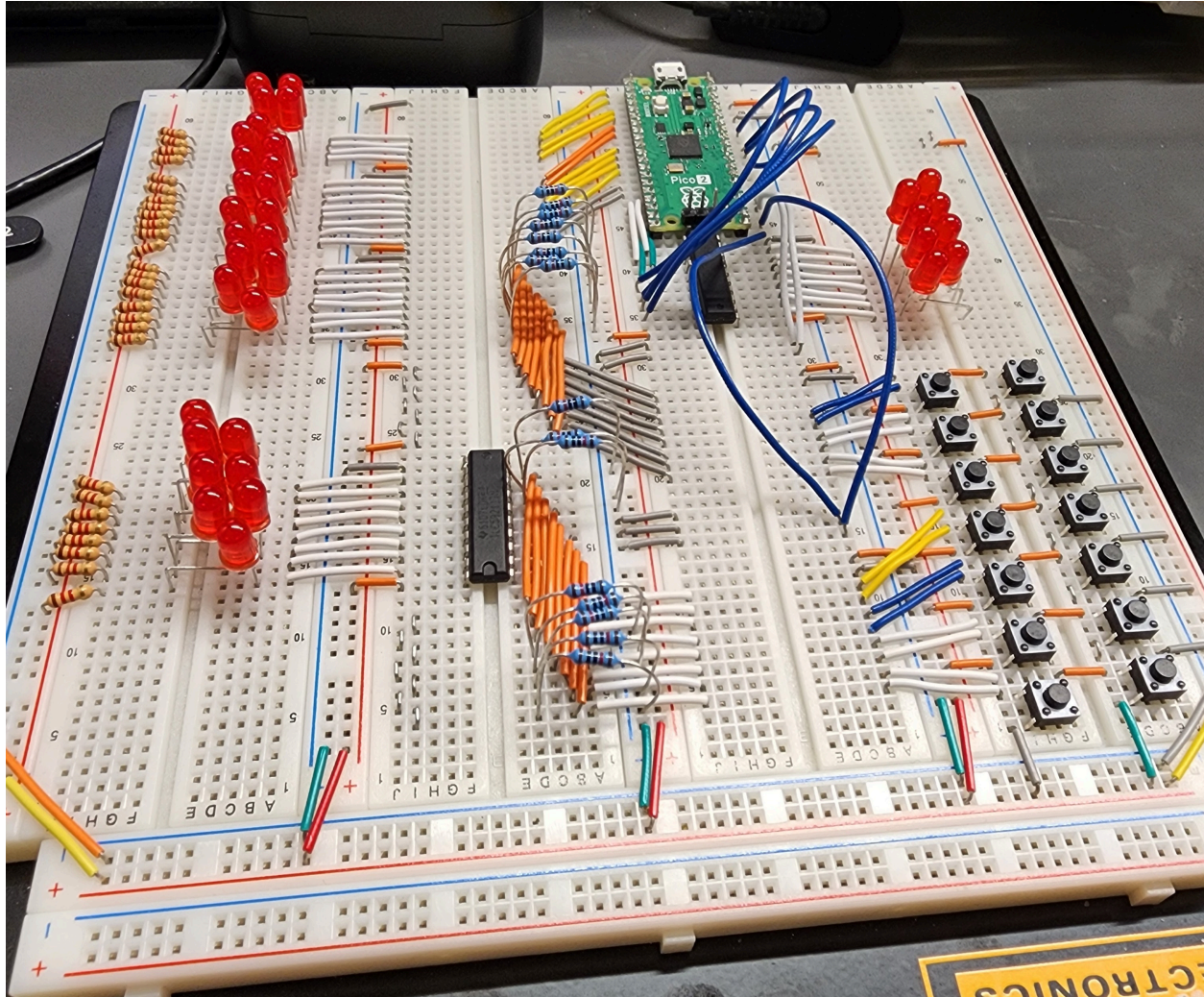
I then power the pico up over USB and the board LEDs lit up.

I noticed the switch LEDs were still shining

I asked brian why and he noted there weren't pull down resistors and that the switch inputs leading to the LEDs were in a floating state.

I added 10k pullup resistors (the ones in the middle below) and the weird LED behavior went away.

And here is a partially disassembled view of the final setup of the front panel breadboard:

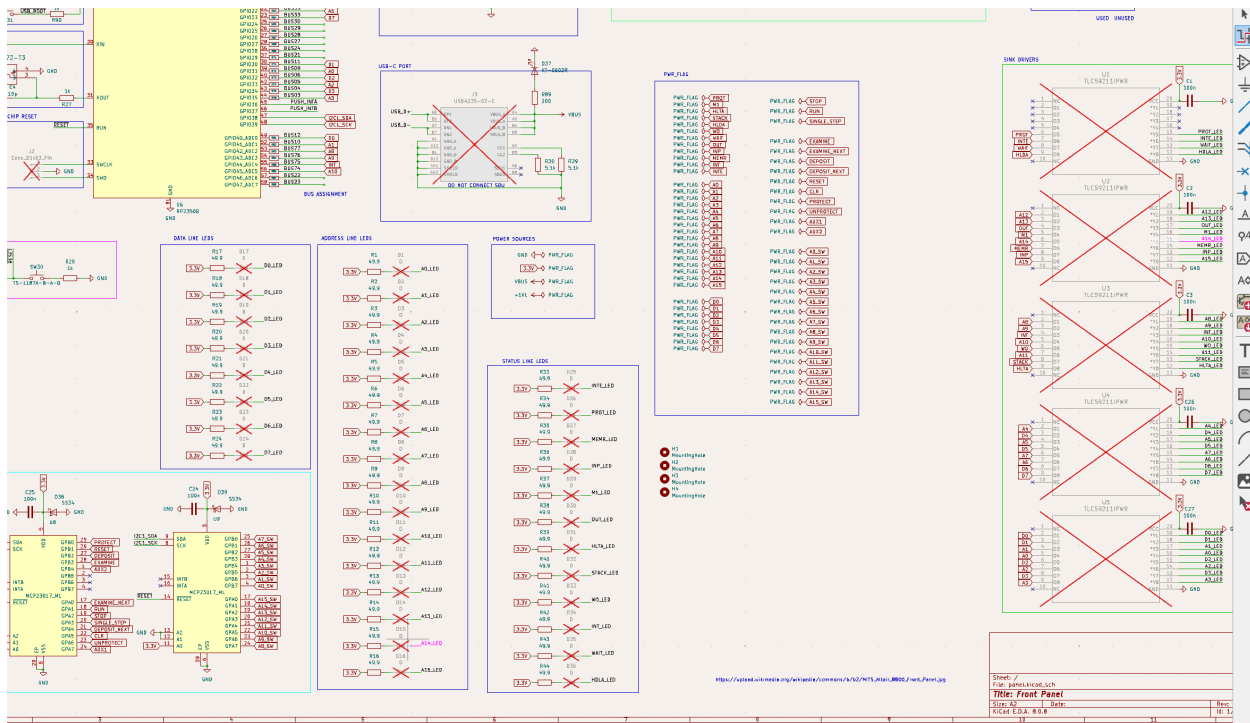


However, I realized that the LEDs in this configuration are directly connected to the switch inputs and are not individual inputs like they are on our production board. Additionally, getting this breadboard to be able to connect with our other dual-stamp bus breadboard so I could use the LEDs as bus debugging LEDs was going to basically be impossible because I had already used up all the GPIO pins on the raspi pico. I could have used our third stamp which had more pins to replace the pico and then bridged that over, however that would take a lot of work rewiring.

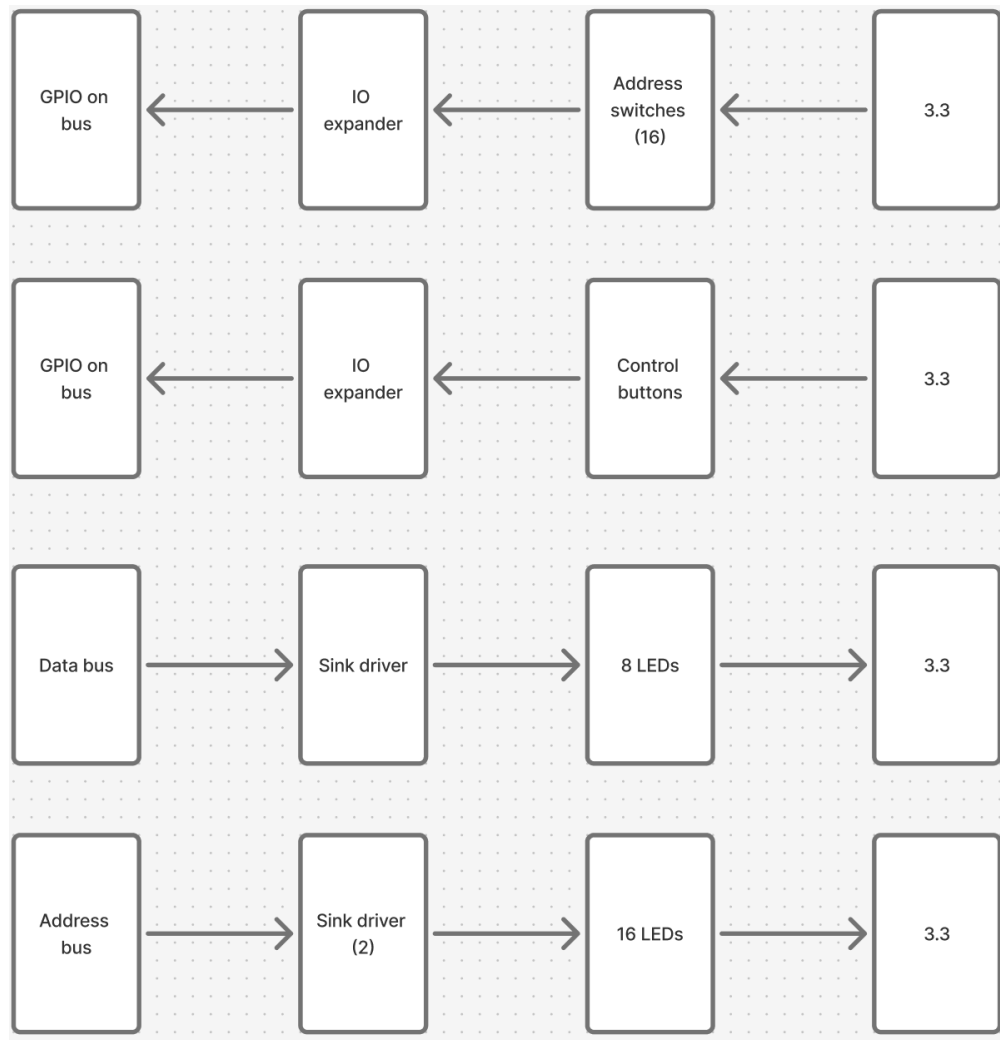
Instead I opted for a more concise solution where we would move all the switches, buttons, and LEDs of the front panel, to just the main bus breadboard and have one of the two stamps act as the microcontroller for the front panel, and the other act as both the cpu and the memory. This would consolidate all of our testing down to one breadboard and be much simpler to wire than adding a third stamp.

First I investigated how I was going to route this. I pulled up the schematic for the current front panel and noted all of the connections again using the highlight nets tool.

Here is one such connections (highlighted pink):

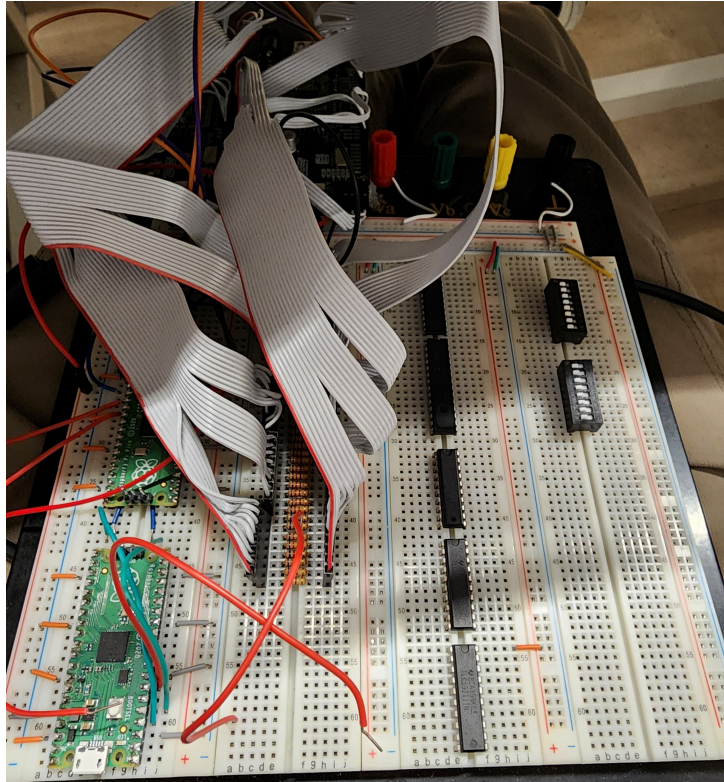


I then made a schematic in Figjam to plan the the ordering and all of the stages, just to verify they would all fit on the breadboard:



Now that I knew I had enough pins to put all the IO Expanders and sink drivers on one row, and the switches, buttons, and LEDs on another, I placed them there:





I then began routing the rest of the board.

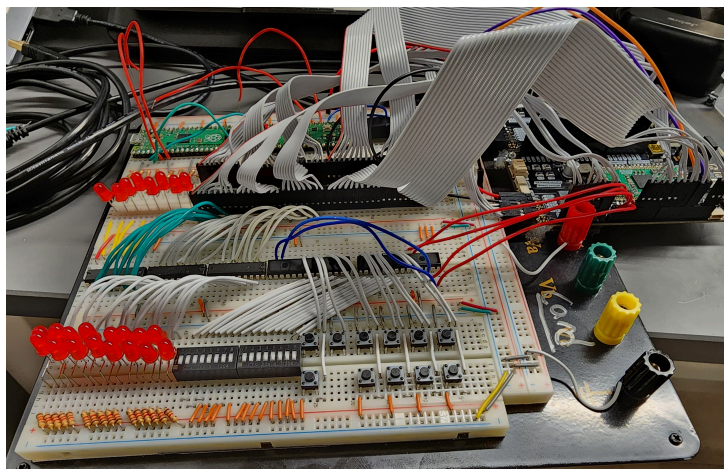
I figured out all 24 LEDs weren't going to fit in the second column cause the switch arrays each took up 2 extra pins, so I moved the data LEDs to next to the bus on the second row.

I then placed the address LEDs at the bottom in the 4th row, moved the switches down next to them, and then placed the buttons. This had enough room so it worked perfectly.

I then began wiring up the LEDs to the sink drivers, the sink drivers to the bus, the buttons and switches to the IO expanders, and the IO expanders to the bus. We are using 2 interrupt pins on one of the io expanders, so I added those to directly to the stamp board because we needed to reserve enough pins for the other simulated bus signals.

Finally I routed the power and checked all the wiring.

Here is the final wiring:



I plugged it in and it appeared nothing was smoking!

I didn't notice any LEDs were on but this was expected since none of the GPIO pins were being driven.

I wanted to get the LEDs working so first I programmed a blinky program to light up the LED on pin 47. It worked. Pin 47 linked to the data LED on the far upper left of the board as shown above. It blinked, however, it was very dim. I wasn't sure why it was very dim vs. the first board where the LEDs lit up more strongly. Maybe more current drained on the bus pins?

Anyways, the LEDs/bus GPIO outputs were confirmed to be working, so I then moved onto confirming the switches and buttons worked as inputs.

I needed to figure out how I2C worked again and what messages were transferred on our MCP23017.

I used chatgpt for this to give me a quick overview of I2C again and I looked at the IC datasheet to learn that the MCP broadcasts the values of its registers over I2C.

I then needed an I2C example from our HAL library, embassy, and [I found one](#). Luckily, the example actually was personally made for the MCP23017 and I could use the code immediately. I realized the original code used `read_write()` functions and I thought these weren't necessary for basic reads, so I replaced them with `blocking_read()`.

I also realized from the datasheet that the MCP doesn't have pull down resistors. only pull up. So I needed to reroute all switches and buttons to ground instead of 3.3 which I had them before.

Here is the first iteration of testing code with these changes:

```
use mcp23017::*;

info!("init mcp23017 config for IxpanDO");
// init - a inputs, b inputs
i2c.write(ADDR, &IODIRA, 0xff).await.unwrap(); // all inputs
i2c.write(ADDR, &IODIRB, 0xff).await.unwrap(); // all inputs
i2c.write(ADDR, &GPPUA, 0xff).await.unwrap(); // pull up inputs
i2c.write(ADDR, &GPPUB, 0xff).await.unwrap(); // pull up inputs

loop {
    let mut porta = [0];
    let mut portb = [0];

    // Read from port A (buttons)
    //i2c.blocking_read(ADDR, &mut porta).unwrap();
    //info!("porta = {:02x}", porta[0]);

    // Read from port B (switches)
    i2c.blocking_read(ADDR, &mut portb).unwrap();
    info!("portb = {:02x}", portb[0]);

    Timer::after_millis(500).await;
}
```

I then built and flashed this program to the stamp and it began to run.

I noticed though that as it was running, it wasn't always outputting the value of one of the switch arrays after the `portb` line. it only did it like every 7 messages like here:



```
2.012589 INFO portb = 7c
└─ interchange::___embassy_main_task::{async_fn#0} @ src\main.rs:115
```

I had run out of time for the day so I saved fixing this issue for tomorrow.

## Week 9

### Entry 2

3/13 Thursday

10pm-1:30am

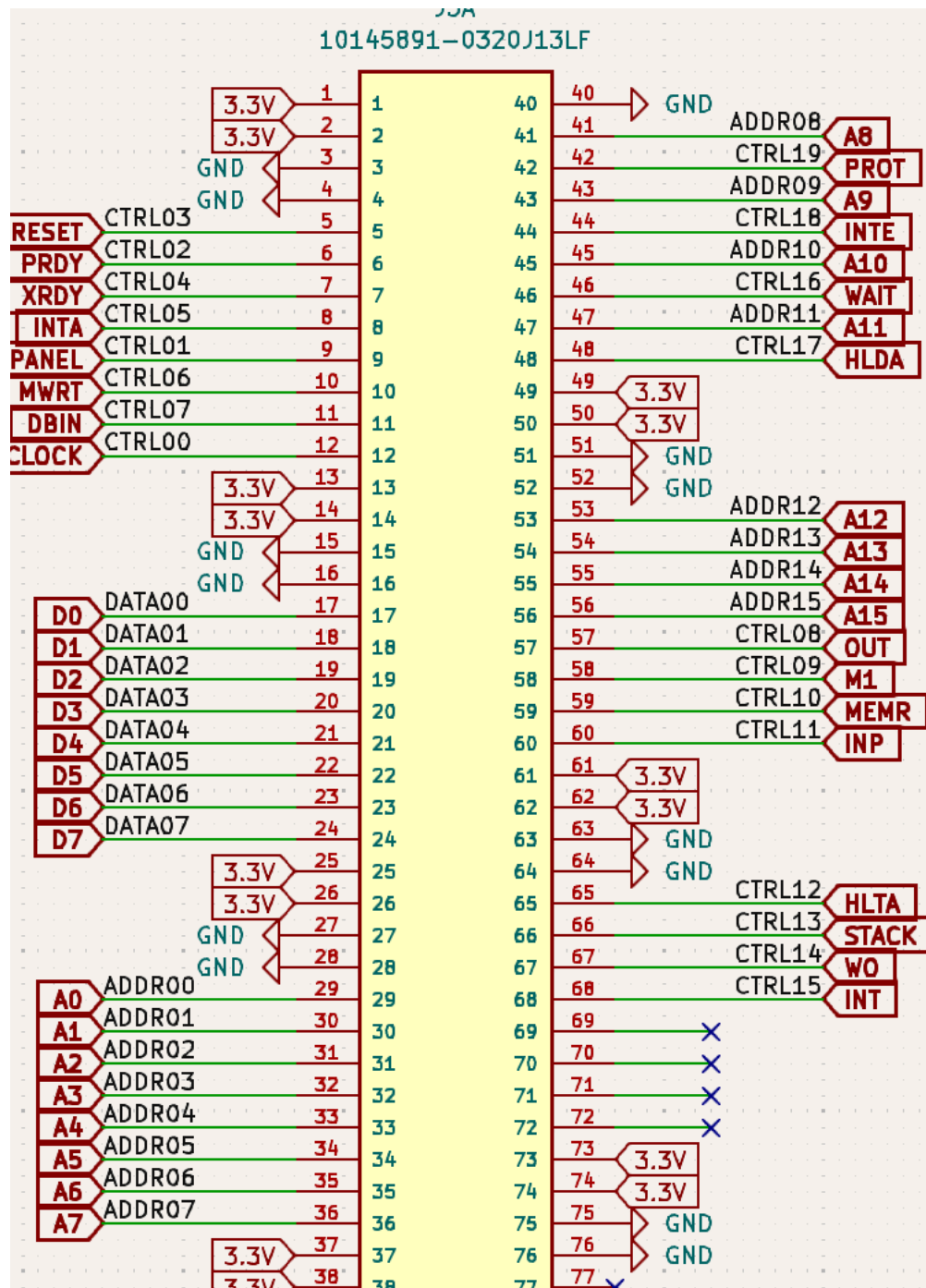
3.5 hours

Today I needed to figure out if we were going to keep the Brian designated/non-essential pin order for the cards/dimm and route more difficult, or maybe switch their positioning up based on what pin order the card is in.

As you can see, the pin order for the front panel is not organized very well. The data and address pins are not next to each other. This was to make routing on the front panel easier



Meanwhile the pin functionality order was organized for the cards:



So first, I needed to learn if the PIO pins do need to be next to each other to send data over the bus. I looked up how to send parallel bus signals using PIO since I couldn't find any Embassy examples that did that. I found this [Raspi forum post](#) showing how to do it. They just needed to add the line

```
pio_sm_set_consecutive_pindirs(pio, sm, 0, 8, true);
```

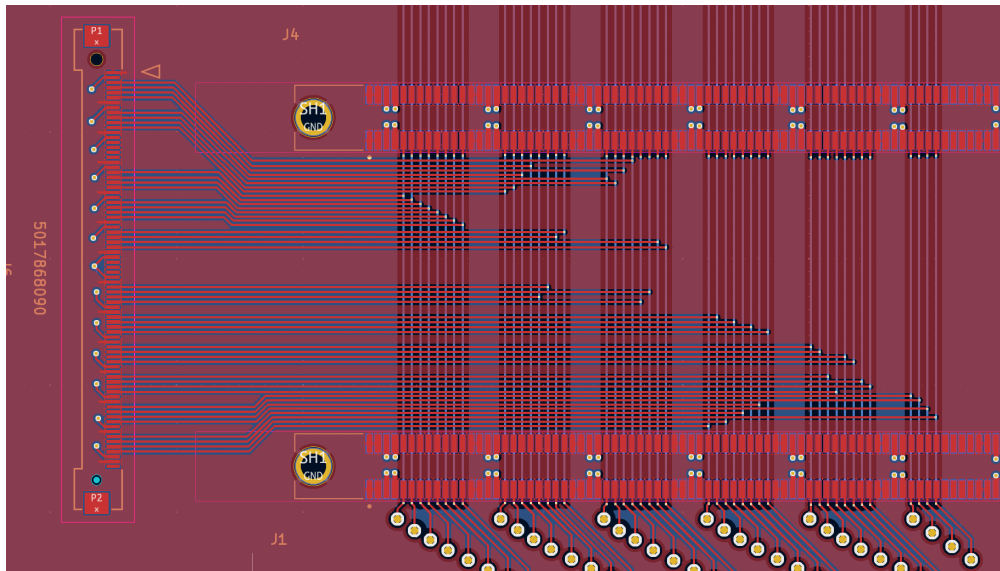
This gave me some indication that you can only setup output pins that are consecutive.

Then I confirmed that setting consecutive pins was the only way to set out pins for the Embassy rust package (the one we're using) and this was correct:

```
pub fn set_out_pins(&mut self, pins: &[Pin<'d, PIO>])  
    Sets the range of pins affected by OUT instructions. The range must be consecutive. Out pins must configured as outputs using  
    StateMachine::set_pin_dirs to be effective.
```

So if the pins need to be next to each other for the card and moving them around in SW would be bad, then it would make sense to keep their ordering and route them criss cross to the corresponding backplane/ffc connector pins.

Nathan took over backplane routing from here so he did the criss-cross layout of the traces based on their assigned functionality:



Since Brian was cleaning up the front panel, the card was done, and Nathan was working on the back, I decided to get started researching how much our PCB order was going to cost.

I exported our card PCB as gerber files and went to JLC PCB's website.

Our PCB was processed successfully and here is the configuration chosen:

Detected 4 layer board of 32.25x133.35mm(1.27x5.25 inches). [Gerber Viewer](#)

[Back to Upload File](#)

Base Material: ☒ FR-4 ☐ Flex ☐ Aluminum ☐ Copper Core ☐ Rogers ☐ PTFE Teflon

Layers: 1 2 **4** High Precision PCB 6 8 10 12 14 16 More

Dimensions: 133.35 \* 32.25 mm

PCB Qty: 15

Product Type: ☒ Industrial/Consumer electronics ☐ Aerospace ☐ Medical

**PCB Specifications**

Different Design: 1 2 3 4

Delivery Format: ☒ Single PCB ☐ Panel by Customer ☐ Panel by JLCPCB

PCB Thickness: 0.4mm 0.6mm 0.8mm 1.0mm 1.2mm **1.6mm** 2.0mm

PCB Color: ☒ Green ☐ Purple ☐ Red ☐ Yellow ☐ Blue ☐ White ☐ Black

Silkscreen: ☒ White

Material Type: ☒ FR4-Standard TG 135-140 ☐ FR-4 TG155 ☐ FR-4 TG170

Surface Finish: ☒ HASL(with lead) ☐ LeadFree HASL ☐ ENIG

Gold Thickness: 1 U" 2 U"

**High-spec Options**

Outer Copper Weight: 1 oz 2 oz

Inner Copper Weight: 0.5 oz 1 oz 2 oz

Specify Layer Sequence: ☒ No ☐ Yes

Impedance Control: ☒ No ☐ Yes [Impedance calculator >](#)

Via Covering: ☒ Plugged ☐ Untented ☐ Epoxy Filled & Capped ☐ Copper paste Filled & Capped ☐ Tented

Min via hole size/diameter: 0.3mm(0.4/0.45mm) 0.25mm(0.35/0.4mm) 0.2mm(0.3/0.35mm) 0.15mm(0.25/0.3mm)

Board Outline Tolerance: ±0.2mm(Regular) ±0.1mm(Precision)

Confirm Production file: ☒ No ☐ Yes

Mark on PCB: ☒ Order Number ☐ Order Number(Specify Position) ☒ 2D barcode (Serial Number) ☐ Remove Mark

Electrical Test: ☒ Flying Probe Fully Test

Gold Fingers: ☒ No ☐ Yes

30°finger chamfered: ☒ No ☐ Yes

Engineering fee: \$24.00

Via Covering: \$0.00

Surface Finish: \$16.80

Board: \$6.60

**Build Time**

PCB: ☒ 3-4 days \$0.00

☐ 3 days **PCBA Only** \$0.00

**Calculated Price** **\$47.40**

Additional charges may apply for special cases

**SAVE TO CART**

**Shipping Estimate** \$7.40

Global Standard Direct Line 8-13 business days

Weight 0.35kg





Coupons

We need about 15 cards 3 cards x 4 machines. And we also needed Gold fingers for our edge DIMM connectors. Finally we need ENIG surface finish since only that is comptible with gold fingers. This came out to be \$47.

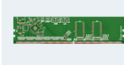
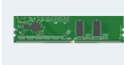
Then we needed to have JLC do assembly as well because that's the only way we can get our microcontroller on the board. I clicked on the assembly tab and it requested a BOM and placement file. I exported the BOM from kicad from the fabrication outputs but I was unsure how to get the placements. I thought location from fabrication output would be good, however, it failed to upload.

I then googled how to get this placements file and i came across the JLC PCB kicad extension [Fabrication Toolkit](#). This makes it easy for you to export all the files needed for JLC so I downloaded it and used it and the placement file it generated worked. I then saw all the parts that JLC had and proceeded and got my final assembly cost.

For 10 cards:

<div> All (1) JLPCB (1) JLC3DP (0) JLCCNC (0) JLCMC (0) </div>					
<input type="checkbox"/>	Item	Qty	Build Time	Price	
<input type="checkbox"/>	JLPCB (PCB/PCBA/Stencil)				
<input type="checkbox"/>	<div>  <div> <b>owo_Y1</b>  PCB prototype:Y1-9553235A  Green, 1.6 Thickness, ENIG  <a href="#">Product Details</a>   <a href="#">Edit Order</a> </div> </div>	10 ▾	3-4 days	<b>\$50.80</b>	
	<div>  <div> <b>owo_Y1</b>  Standard PCBA: SMT025031460292-9553...  Assemble top side  <a href="#">Product Details</a> </div> </div>	10 ▾	2 - 3 days	<b>\$116.59</b>	

For 15:

<input type="checkbox"/>	<div>  <div> <b>owo_Y1</b>  PCB prototype:Y1-9553235A  Green, 1.6 Thickness, ENIG  <a href="#">Product Details</a>   <a href="#">Edit Order</a> </div> </div>	15 ▾	3-4 days	<b>\$56.30</b>	
	<div>  <div> <b>owo_Y1</b>  Standard PCBA: SMT025031460292-9553...  Assemble top side  <a href="#">Product Details</a> </div> </div>	15 ▾	2 - 3 days	<b>\$138.99</b>	

As you can see, there's not much difference when you scale. The assembly price was quite a lot.

If we were to get 10 cards, that would be around \$170 and our enclosures which also are a large cost that we already know are \$39 each, would come out to \$160 for 4. That is \$330 spent with only \$280 left for the 5 front panel cards and the 5 back panel. It maybe should be enough? The front panel has a lot of components though so I'm a bit concerned. I will wait and see how much those are calculated as since I am going to bed now. Brian and Nathan will calculate them in the morning before the order them. This gives us a good idea now though on what we can and can't order and where we could cut costs.

As for me, my next steps is to get going on the software over break. I have brought home our development breadboards so I can work on sw over break. I will need to complete tram over break to stay on schedule. I'd also like to do cycle (CPU) and interconnect (front panel) since then I won't have to do work on the week after break. I have a good understanding of PIO and how output works now that I know how the consecutive pin output assigning works for a parallel bus so I am confident i can get a bus implementation with state machines working quickly.

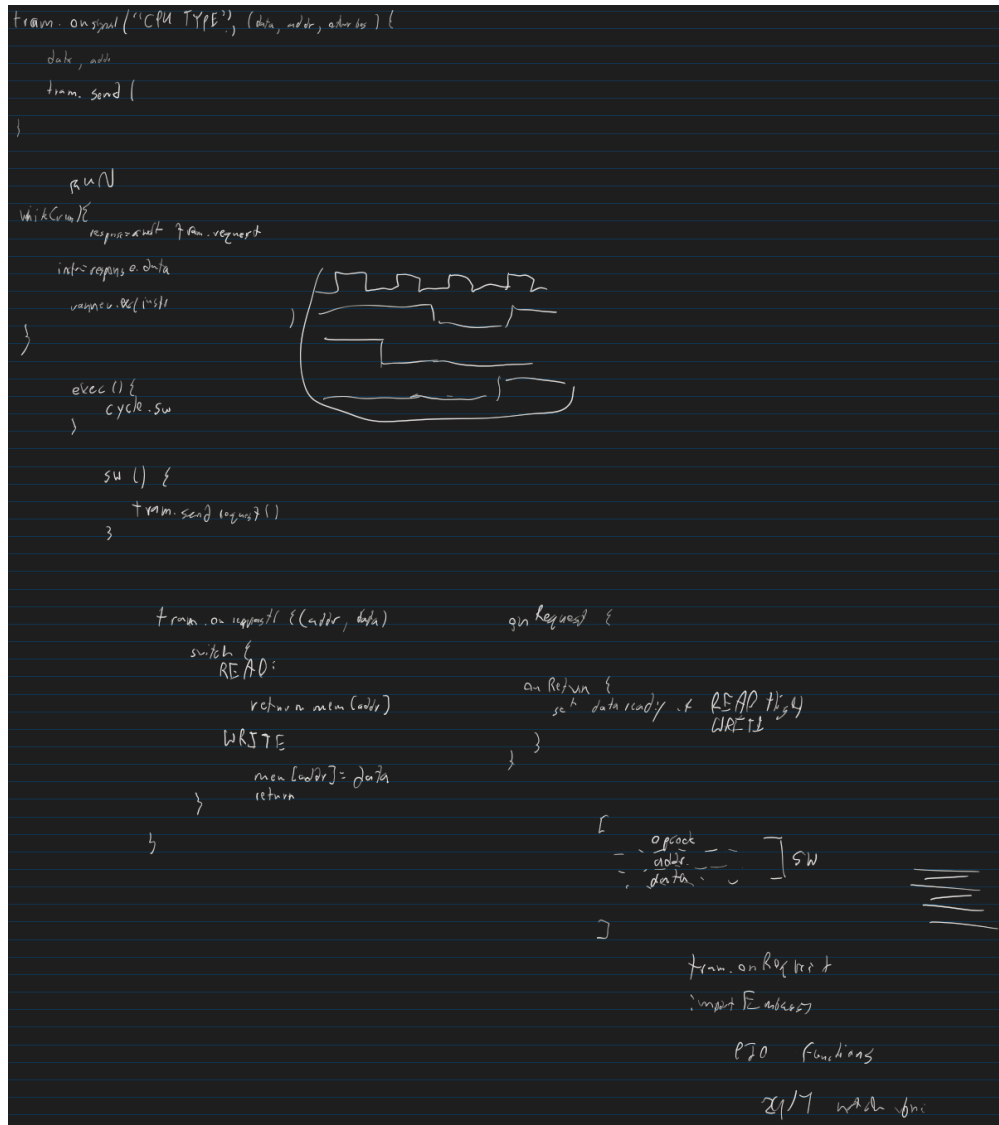
## Entry 1

3/12 Wednesday

8pm-2am

6 hours

Today I first talked with Caleb about how our software stack is going to work.



I made the diagram above to explain that retrieving instructions from memory takes actually 3 clock cycles and that tram would handle doing memory reads and the CPU firmware would not worry about that. That is why tram is its own package. As you can see, I also wrote some pseudocode on how we could use async/await, callback functions and event listeners to create onRequest and sendRequest functions for tram and then exec instructions for exec. This helped me better understand the software stack and I copied this pseudocode in a new firm over to our tram repo and got started on it.

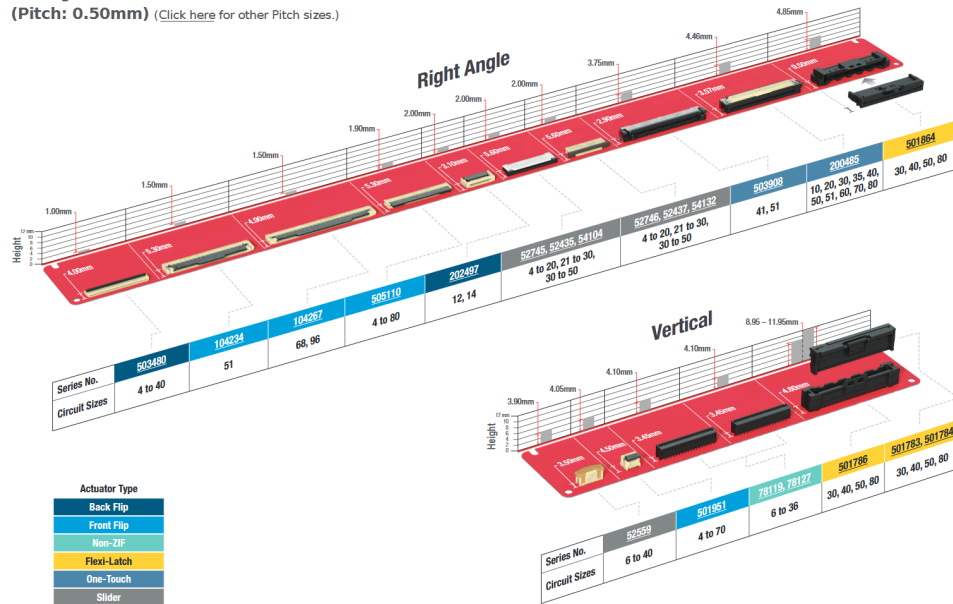
Next I went back to working on our backplane since I realized that we need to add the connector that will link the front panel with the back panel. The connector will not be a DIMM connector. I knew it was going to be a ribbon cable. I learned Nathan had previously chosen an FFC connector for the front panel, so I looked at the [datasheet](#) for that to get a better idea of how it works. I also googled/chatgpted what the difference between an FFC and FPC connector/cable is since the datasheet uses both terms. FPC is like a printed circuit in the cable so we only care for FFC type ribbon cables.

I also inquired Nathan why he chose this connector since it is quite large. I learned that we need an 80 pin connector for all our bus signals and Molex only makes 80 pin connectors that are in this size. We also needed a vertical FFC connector and Molex only makes them in this formfactor too.

I found this Molex product guide and it shows all their connector types

## Easy-On FFC/FPC Connectors

**(Pitch: 0.50mm)** ([Click here](#) for other Pitch sizes.)



As you can see, the lareset is the only vertical one that supports that many pins. and has a nice clip.

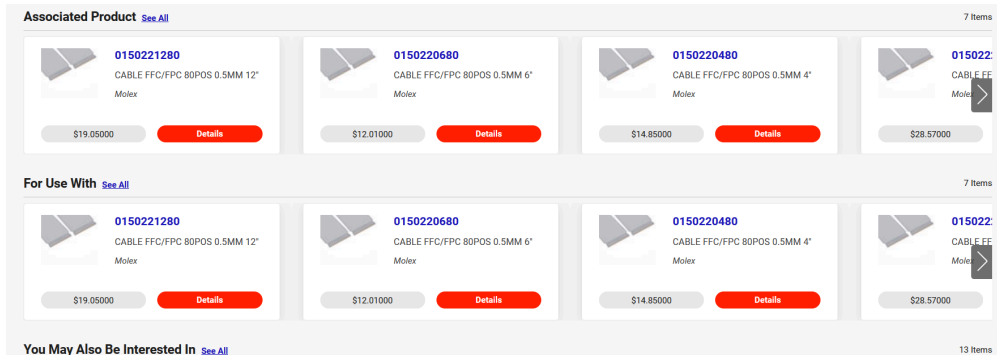
Now that the connector was confirmed, I needed to find a compatible cable for it. I noticed on the datasheet it said the connector was compatible with a certain type of jacket. I didn't know what a jacket was so I looked that up and it is a plastic housing that protects cables that goes on the outside of an FFC cable. Here were the Jackets that were compatible with our connector:

Use with Part(s)

Description	Part Number
0.50mm Pitch FFC-to-Board Plug Jacket, 80 Circuits	<u>5017838009</u>
0.50mm Pitch FFC-to-Board Plug Jacket Cover, 80 Circuits	<u>5017848009</u>

I chose the 783 variant and found its part on digikey. Then I just needed the cable.

I tried using [Molex's website](#) to find compatible cables, however, they didn't have a filter for finding cables based on compatible connectors so I was very lost. Until, I went to [digikey's website](#)! When I pulled up the [Digikey page](#) for our connector, there was a compatible parts section at the bottom that showed which cables were compatible:

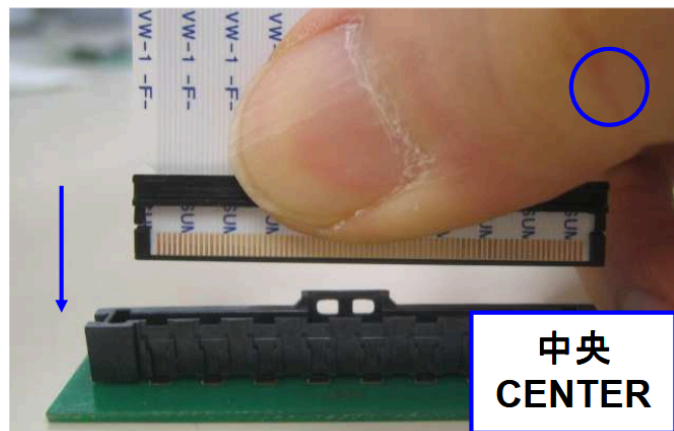
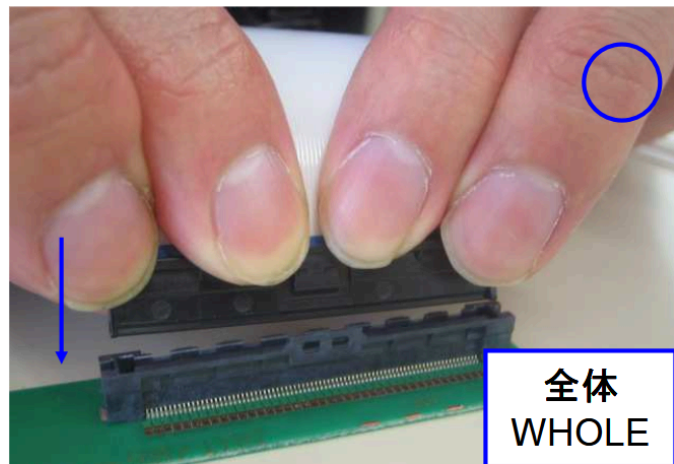


Here were all the variants! In the future, I now know I should probably search for parts using distributor websites since they are going to be the ones I'll be buying the product from in the end and they have better filters as well. I just didn't know they sold these as I struggled to find them in the first place.

The cables were all different sizes. We only need a small ribbon cable. Unfortunately the 2 in ones were sold out so I selected the 4 inch one.

Next I need to figure out what the cable looked like and how it was inserted, just to make sure how it was going to work with the jacket and such. I found the product specification from Molex for the connector and inside of it, it shows the jacket and how the cable is oriented inside of the jacket:

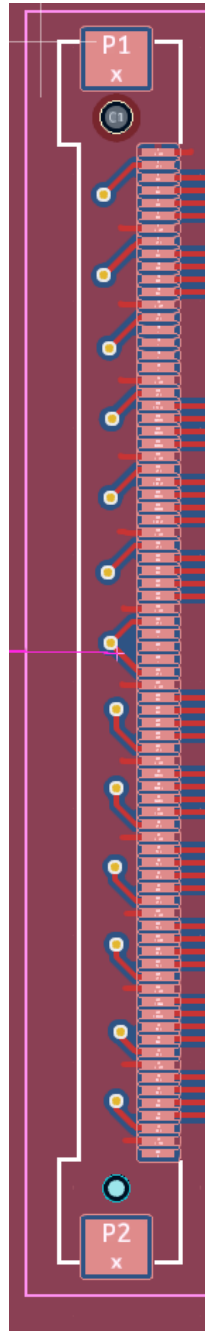
When mating the connector, hold the JACKET AND JACKET COVER together at either a whole or the center portion of them to insert.





With this knowledge, I now know that we need to orient our connectors for the frontplane and backplane to match which way the ribbon will be pointing so that the connectors are on the right side. The cable only has connectors on one side so this is why it is important.

I placed the connector in our PCB layout for routing later:



I also learned from brian how to import the 3D model for it from digikey because it originally wasn't showing up in the 3D view for the backplane. Now it does:



Ok, now that the FFC connector is sorted, I also realized that a power switch was missing from the backplane. This needs to be a vertical power switch that will show through a cutout on the front panel. To fin this part, I simply looked for in-stock vertical 2 way switches on Digikey. Here is the cheapest option I found and it fits our needs:

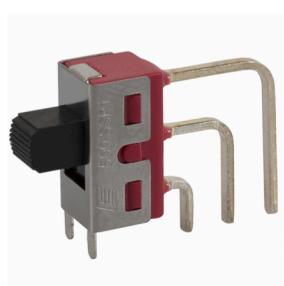



Image shown is a representation only. Exact specifications should be obtained from the product data sheet.



### 500SSP1S1M7QEA

DigiKey Part Number	EG2480-ND
Manufacturer	<a href="#">E-Switch</a>
Manufacturer Product Number	500SSP1S1M7QEA
Description	SWITCH SLIDE <a href="#">SPDT</a> 5A 120V
Manufacturer Standard Lead Time	11 Weeks
Customer Reference	<input type="text"/>
Detailed Description	Slide Switch SPDT Through Hole, Right Angle, Vertical
Datasheet	<a href="#">Datasheet</a>
EDA/CAD Models	<a href="#">500SSP1S1M7QEA Models</a>

I needed the 3D model for this and footprint so I learned how to get to digikey's footprints page and import it into kicad:

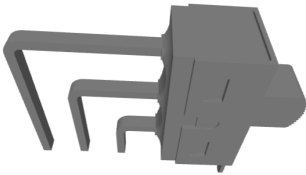


**500SSP1S1M7QEA**  
E-Switch  
SWITCH SLIDE SPDT 5A 120V

Model Feedback

Manufacturer EDA and CAD Models

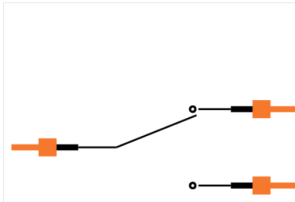
[500SSP1S1M7QEA.stp](#)



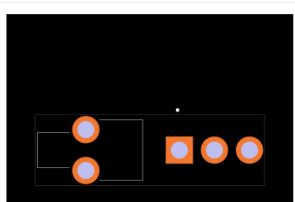
Download  
500SSP1S1M7QEA

SnapMagic

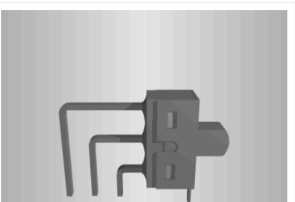
Symbol



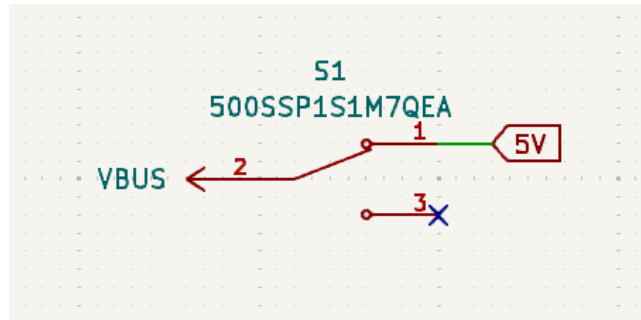
Footprint



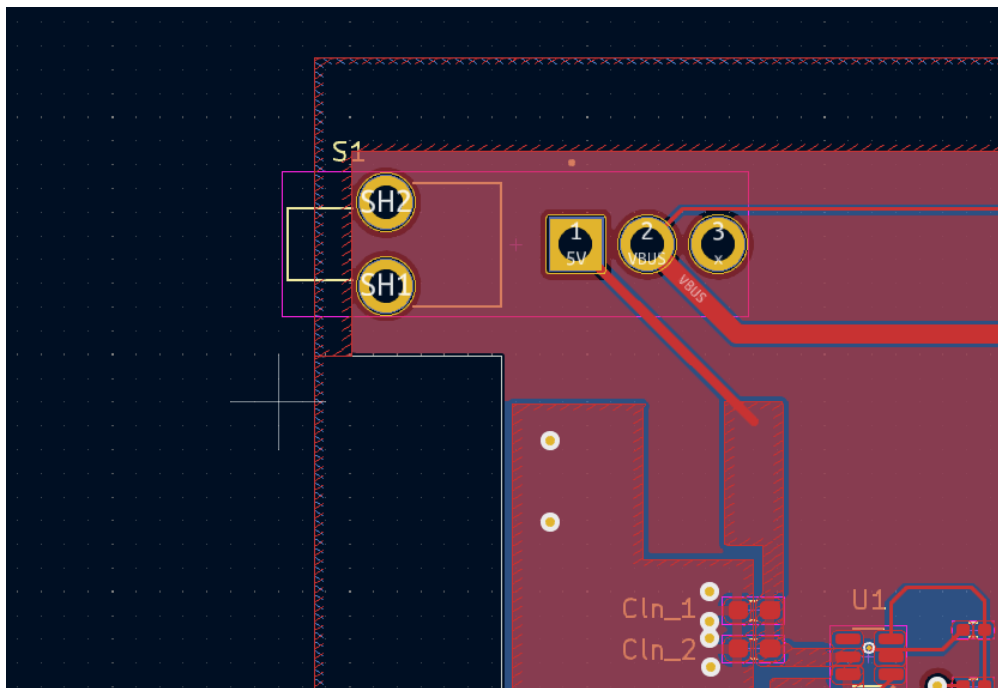
3D Model



I then added it to the schematic:



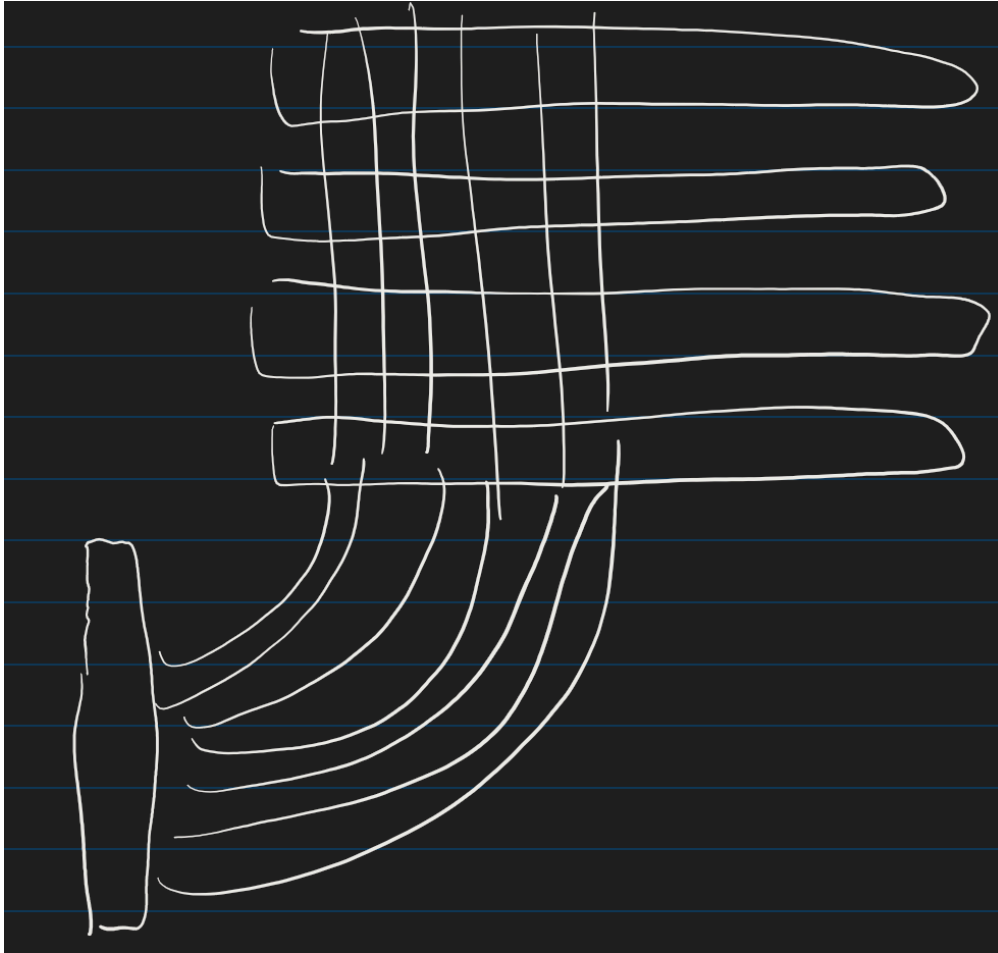
And inserted it into the layout where it needs to go on the left side of our backplane:



The final thing to do was to route the FFC connector to the DIMM slots. Only thing was that Brian was still working on the pin assignments for the front panel and which order they were going to be for the front panel connector, so I waited a bit.

Brian finished, however I realized that the pin order does matter for the front panel but for the cards/DIMMS it does not. We can change the pin functionality in software.

So I thought, maybe it would be easy then to route them like this:



But I wasn't so sure. Because maybe the card pin order *does matter* because the PIO pins need to be next to each other. I wasn't sure because I hadn't done my own programming in PIO yet so I waited for next morning to figure out what to do about this.

## Week 8

### Entry 1

3/4 Tuesday

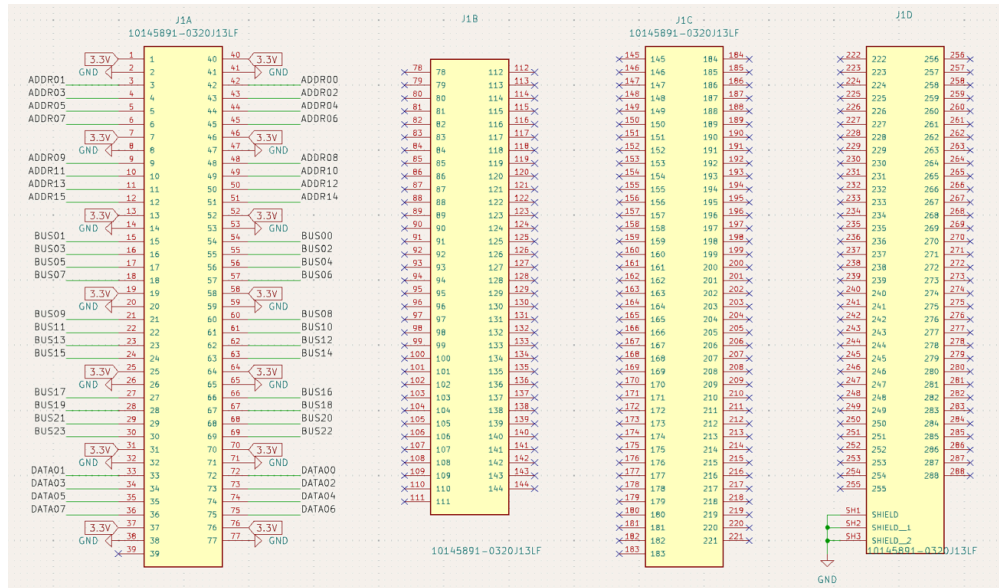
10:30pm-10am

11.5 hours

Today we needed to finish all the pcb layouts and insert them into our presentation that was for the next day.

I realized that we had not started on our backplan PCB schematic and layout so I took to getting that done while my teammates worked on the other PCBs and slides.

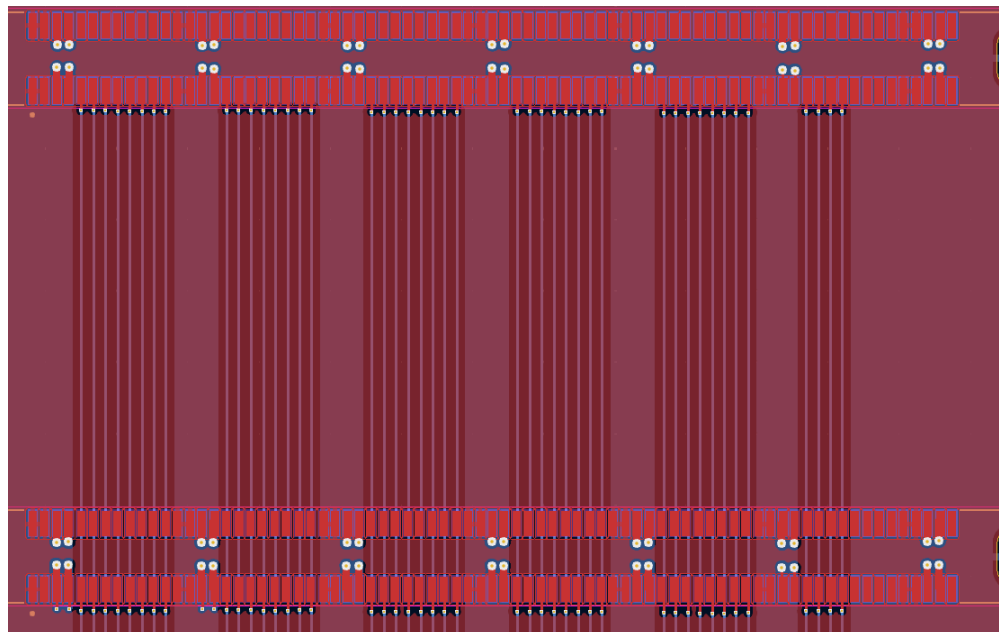
First I needed to figure out how I was going to do the schematic for the dimm slots. Here is what I assigned them nets.



I then copied this 4 times. We chose SMD Dim slots as they can be more easily routed for a bus than through hole ones as I learned from an earlier layout experiment.

Then I went to PCB layout for the bus.

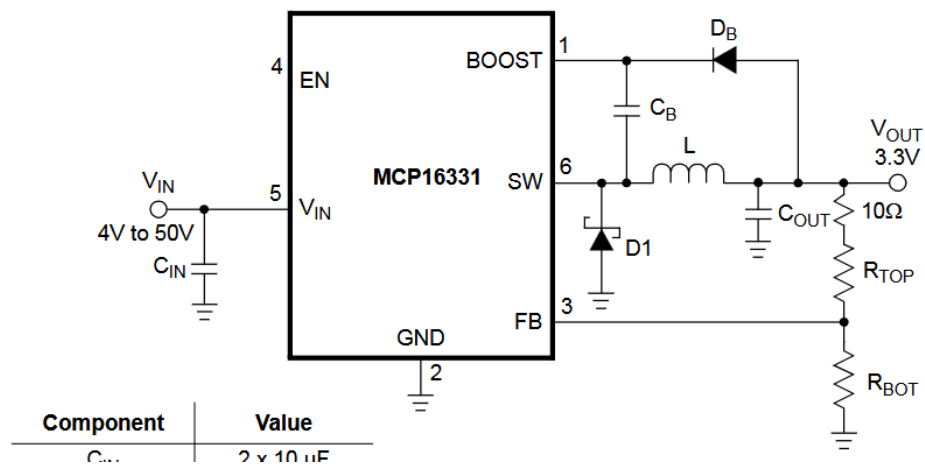
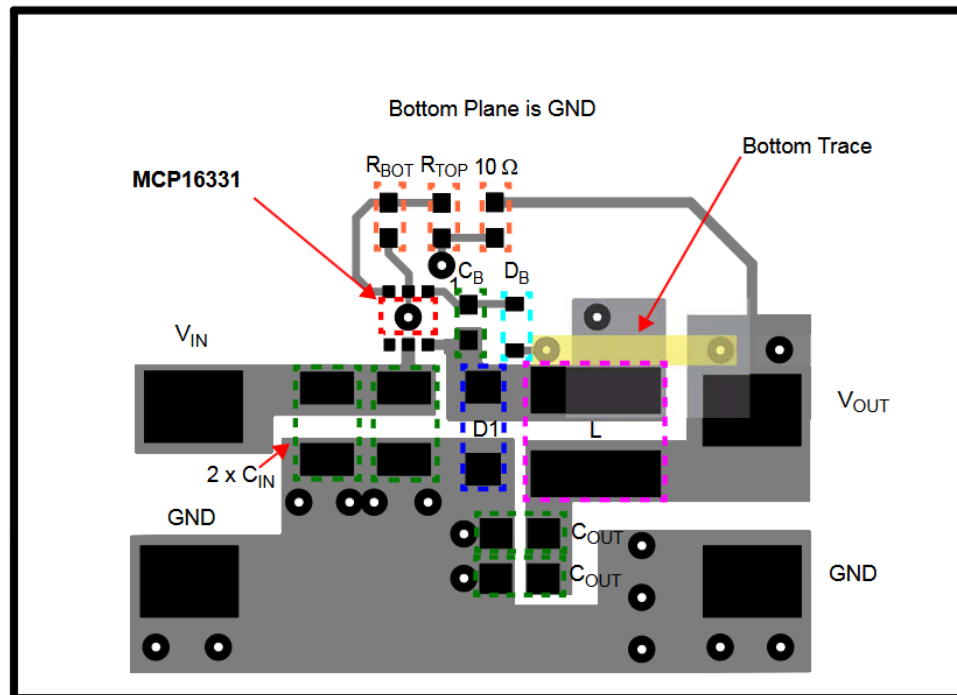
I routed them in the below fashion where bus signals are viaed to the bottom layer and all share a bottom copper strip. Power and ground which are after every block of signal pins, get zone-linked either for the front layer (for power) or through vias to the back layer (for ground).



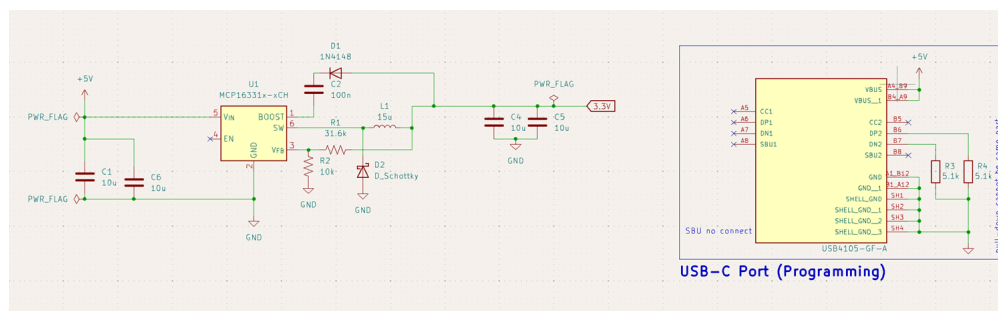
As I did this, Brian showed me how to use KiCad. I learned all the key shortcuts, how to import new footprints and models, how to set a custom grid, and how to make zones.

After laying out the DIMM slots, I proceeded to research the buck converter and recommended layout to place on the backplane.

Here was the reference:



And here was my implementation with the USB C port as well









Clock always running

Single step just triggers a flip flop to have the pc attach to the main clock.

Examine sends a jmp instruction (jmp, upper, lower)

1. Flip On switch (deliver power to all PCBs, microcontrollers start, set front panel = stop, CPU pc = 0)
2. Program first instruction
  1. First byte
    1. You're already in data mode. Flip the switches to change the data line. Lights do not change
    2. Hit deposit. Data lights should change to switch values.
  2. Second byte
    1. Flip switches to change data line
    2. Hit deposit NEXT. Address lights flip to mem address 1, data line reflects switches.
  3. X byte ...
3. Examine byte
  1. Flip switches to address you want to examine
  2. Hit Examine. Data lights should change.
4. Running
  1. Hit Stop, Reset (goes to mem location 0, reset does not clear memory)
  2. Hit single step. Will execute machine cycle

I was still curious about all the bus signals we had and I wanted to make a better version of this diagram

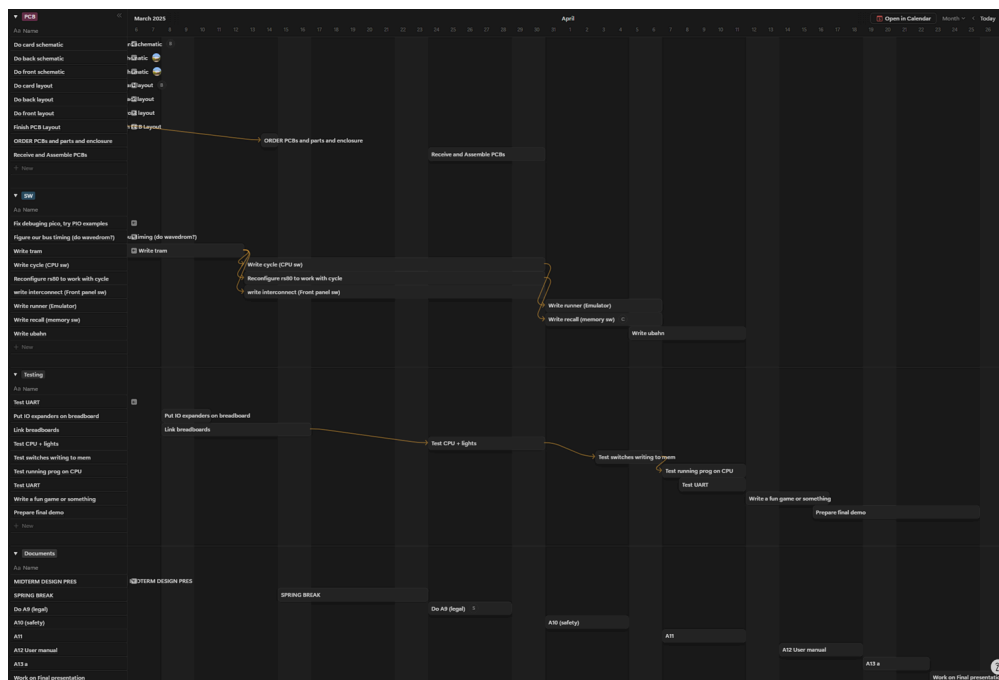
Bus Mapping																						
																						CPU
																						RAM
																						Panel
CLOCK	PRESET	PANEL	PROT	SM1	SHLTA	SSTACK	PHOLD	PDBIN	SWO	PWAIT	PRDY	SOUT	SINP	XRDY	MWRT	SMEMR	PINT	SINTA	PINTE	A{15:0}		D{7:0}
4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	GPIO 24-39		GPIO 40-47
Control	UI			Status		DMA		R/W				I/O		Memory			Interrupt			Address		Data

that was vertically oriented and also included the description and category so I made this:

GPIO #	Type	Name	Description	Ownership		
4	Control	CLOCK	bus clock	Panel		
5	Control	~PRESET	reset	Panel		
6	UI	PANEL	front panel data control	Panel		
7	UI	PROT	memory protection	Panel		
8	Status	SM1	first machine cycle of instruct	CPU		
9	Status	SHLTA	halt	CPU		
10	Status	SSTACK	stack operation	CPU		
11	DMA	~PHOLD	hold bus control			
12	R/W	PDBIN	data bus in	CPU		
13	R/W	SWO	write-out	CPU		
14	R/W	PWAIT	mem/io	CPU		
15	I/O	PRDY	io ready			
16	I/O	SOUT	output IO cycle	CPU		
17	I/O	SINP	input io cycle	CPU		
18	Memory	XRDY	memory ready	RAM		
19	Memory	MWRT	memory write strobe	CPU		
20	Memory	SMEMR	memory read strobe	CPU		
21	Interrupt	~PINT	interrupt request			
22	Interrupt	SINTA	interrupt acknowledge	CPU		
23	Interrupt	PINTE	interrupt enable	CPU		
24-39	Address	A{15:0}				
40-47	Data	D{7:0}	tri-state	CPU	RAM	Panel

and added it to the presentation.

The final part of the presentation that needed to be completed was our timeline. I already had setup our project timeline in Notion, I just needed to add more events to it and adjust it for the end of the semester. I figured out that Spring break will cut off an entire week however, we can still get all our software down if we complete our packages around 1 a week and we will have 2 week of room at the end in case.



Next steps will be to receive presentation feedback and continue finishing our PCB designs for ordering next week.

## Week 7

### Entry 5

2/28 friday

10:30-1pm

2.5 hours

Reading the pio spec in the rp2350 manual. Talking to caleb about how rpa vs rp b pins are specified in the hal project.

Then I continued to try to understand the pio async example program. I learned about all the types of directives in pio assembly code like `wrap` and `wrap_target` and what delay does.

I also learned that side stepping is how you can control multiple pins with a single state machine.

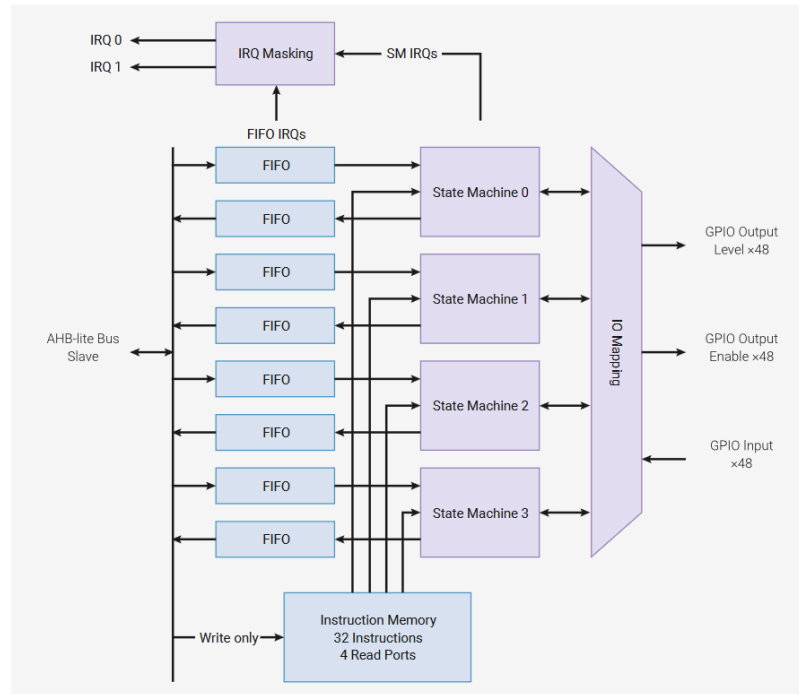
Our microcontroller consists of:

- 3x PIO Blocks
- 4x state machines per block
- 5x GPIO pins per state machine

So we can control about 5 pins per instruction. But then the manual also notes we can shift 30 bits in and out over pins so I think we can do a combination of this. We need to think about this so that we can determine how many state machines we need and what state machines will be controlling what pins on our bus

Here is a good diagram of the layout of the state machines:

Figure 43. PIO block-level diagram. There are three PIO blocks, each containing four state machines. The four state machines simultaneously execute programs from shared instruction memory. FIFO data queues buffer data transferred between PIO and the system. GPIO mapping logic allows each state machine to observe and manipulate up to 32 GPIOs.



Next steps are to write my own pio program for the bus using the programming knowledge I've learned about the PIO standard.

## Entry 4

2/27 Thursday

9:00-11am

2 hour

Ok had debugging problems where embassy doesn't want to consistently program.

Got that resolved and helped caleb get onboarded with rust and probe-rs so he could begin programming the rp2350.

I had brian try debugging like I did and he also ran into the issue of the lines not highlighting and the breakpoints not triggering. We were thinking it's probably a rust compiler thing that the breakpoints are not working as expected. We could look into compile flags to maybe fix this, however, we already have uart and [defmt](#) (a rust logger for embedded devices) setup and that should be good.

Right now i am reading on pio and trying the async pio example from the [embassy examples repo](#). The example will help me figure out how to configure pio and how it works. I'm also using copilot and the [rp2350 datasheet](#) to understand the code and capabilities of each PIO state machine.

```

86 // Repeatedly trigger IRQ 3
87 let prg: ProgramWithDefines<ExpandedDefines, _> = pio_asml(
88     ".origin 0",
89     ".wrap_target",
90     "set x,10",
91     "delay:",
92     "jmp x-- delay [15]",
93     "irq 3 [15]",
94     ".wrap",
95 );
96 let mut cfg: Config<'_, PIO0> = Config::default();
97 cfg.use_program(prg: &pio.load_program(prg: &prg.program), side_set: &[]);
98 cfg.clock_divider = (U56F8!(125_000_000) / 2000).to_fixed();
99 sm.set_config(&cfg);
100 }
101
102 #[embassy_executor::task]
103 async fn pio_task_sm2(mut irq: Irq<'static, PIO0, N: 3>, mut sm: StateMachine<'static, PIO0, SM: 2>) {
104     sm.set_enable(true);
105     loop {
106         irq.wait().await;
107         info!("IRQ triggered");
108     }
109 }
110
111 ► Run | ⏏ Debug
112 #[embassy_executor::main]
113 async fn main(spawner: Spawner) {
114     let p: Peripherals = embassy_rp::init(Default::default());
115     let pio: PIO0 = p.PIO0;
116
117     let Pio {

```

PROBLEMS 12 OUTPUT DEBUG CONSOLE TERMINAL PORTS MEMORY XRTOS PLAYWRIGHT COMMENTS SERIAL MONITOR

```

93.978567 INFO Pulled 101011010110101101011010110110 from FIFO
└ test:: _pio_task_sm1_task::{async_fn#0} @ src\bin\test.rs:79
94.071898 INFO Pulled 101011010110101101011010110110 from FIFO
└ test:: _pio_task_sm1_task::{async_fn#0} @ src\bin\test.rs:79
94.165235 INFO Pulled 101011010110101101011010110110 from FIFO
└ test:: _pio_task_sm1_task::{async_fn#0} @ src\bin\test.rs:79
94.258567 INFO Pulled 101011010110101101011010110110 from FIFO
└ test:: _pio_task_sm1_task::{async_fn#0} @ src\bin\test.rs:79
94.351899 INFO Pulled 101011010110101101011010110110 from FIFO
└ test:: _pio_task_sm1_task::{async_fn#0} @ src\bin\test.rs:79
94.445231 INFO Pulled 101011010110101101011010110110 from FIFO
└ test:: _pio_task_sm1_task::{async_fn#0} @ src\bin\test.rs:79
94.538568 INFO Pulled 101011010110101101011010110110 from FIFO
└ test:: _pio_task_sm1_task::{async_fn#0} @ src\bin\test.rs:79
94.631905 INFO Pulled 101011010110101101011010110110 from FIFO
└ test:: _pio_task_sm1_task::{async_fn#0} @ src\bin\test.rs:79
94.725231 INFO Pulled 101011010110101101011010110110 from FIFO
└ test:: _pio_task_sm1_task::{async_fn#0} @ src\bin\test.rs:79
94.818566 INFO Pulled 101011010110101101011010110110 from FIFO
└ test:: _pio_task_sm1_task::{async_fn#0} @ src\bin\test.rs:79
94.911906 INFO Pulled 101011010110101101011010110110 from FIFO
└ test:: _pio_task_sm1_task::{async_fn#0} @ src\bin\test.rs:79
PS C:\Users\jayan\Documents2\8800\rs\cycle>

```

Testing the PIO standard with the async embassy example. Terminal shows it is working on the microcontroller

Next steps are to continue reading about PIO until I fully understand the standard.

## Entry 3

2/25 Tuesday

11:30pm-5am

5.5 hours

Okay so brian brought another pico and plugged it into the board. First i verified we could program both boards with both picos. From this, I learned one of the picos did not have picoprobe on it, so I quickly flashed that uf2. Then I verified it could flash a program using probe-rs like pio-dma and it did successfully.

I then worked on getting UART over the debug probe to work. I wanted to do this so that we could have one pico send signals over the bus and the other pico confirm that it received those signals by sending a message over UART.

I first looked up the pico debug probe wiring again in the [pico getting started manual](#) and found what RX and TX pins it expected. I then looked through the [rp2350 datasheet](#) to find which pins were available for UART from the GPIO functions table. I decided on pins 42 and 43 as the lower ones were closest to the pico they had to connect to on our breadboard so it was easy to wire.

After wiring, I opened the UART program on [rp-rs-hal examples repo](#) changed the GPIO pins to be used for UART, and tried programming. When it was building it ran into the error that it didn't recognize pins 42 and 43. I looked at the internal code for the package and realized that GPIO pins 42 and 43 were not listed as UART pins. I then realized that the HAL only supported the rp2350-a (60 pin variant) and not the rp2350-b (80 pin variant) that we were using that has the higher pin numbers. [This Github issue](#) confirmed this lack of support. I could add the pins myself but I didn't want to waste time. I remembered [embassy](#) was another rp HAL we could use to program our microcontroller with rust. I checked the pins support and it did support the rp2350b model. We were in luck! I setup our tram project to use the embassy dependencies and added the [uart example](#) and programmed the board with it. I ran into a pin error again but I just needed to change one of the embassy-rp package features from "rp235xa" to "rp235xb".

It looked like it flashed, but when I opened the serial monitor, I wasn't seeing anything on my computer. I then tried adding breakpoints, a probe-rs launch.json file to my vscode workspace, and debugging, however, the breakpoints were not being hit. I think the debug support for our microcontroller isn't fully there yet since it was just added recently. This [issue](#) and [PR](#) might clarify. We may need to install gdb, or use openocd for a debugger instead.

To make sure the uart is working, I'm going to add led flashes when it is sending messages. I looked at the [blinky](#) embassy example to do this in my own code.

I eventually got serial working by switching up some wires and saw it on the console so no LEDs were needed!

```
1  /// This example shows how to use UART (Universal asynchronous receiver-transmitter) in the
2  ///
3  /// No specific hardware is specified in this example. Only output on pin 0 is tested.
4  /// The Raspberry Pi Debug Probe (https://www.raspberrypi.com/products/debug-probe/) could
5  /// with its UART port.
6
7  #![no_std]
8  #![no_main]
9
10 use embassy_executor::Spawner;
11 use embassy_rp::uart;
12 use {defmt_rtt as _, panic_probe as _};
13
14 #[embassy_executor::main]
15 async fn main(_spawner: Spawner) {
16     let p = embassy_rp::init(Default::default());
17     let config = uart::Config::default();
18     let mut uart = uart::Uart::new_blocking(p.UART1, p.PIN_42, p.PIN_43, config);
19     uart.blocking_write("Hello World!\r\n".as_bytes()).unwrap();
20
21     loop {
22         uart.blocking_write("hello there!\r\n".as_bytes()).unwrap();
23         cortex_m::asm::delay(1_000_000);
24     }
25 }
26
```

The embassy-rs UART example that successfully printed Hello World on our serial monitor. It is much less code than the rp-rs package UART example.

Our next step is get PIO working instead of UART as that is the communication interface we will use to build our bus.

## Entry 2

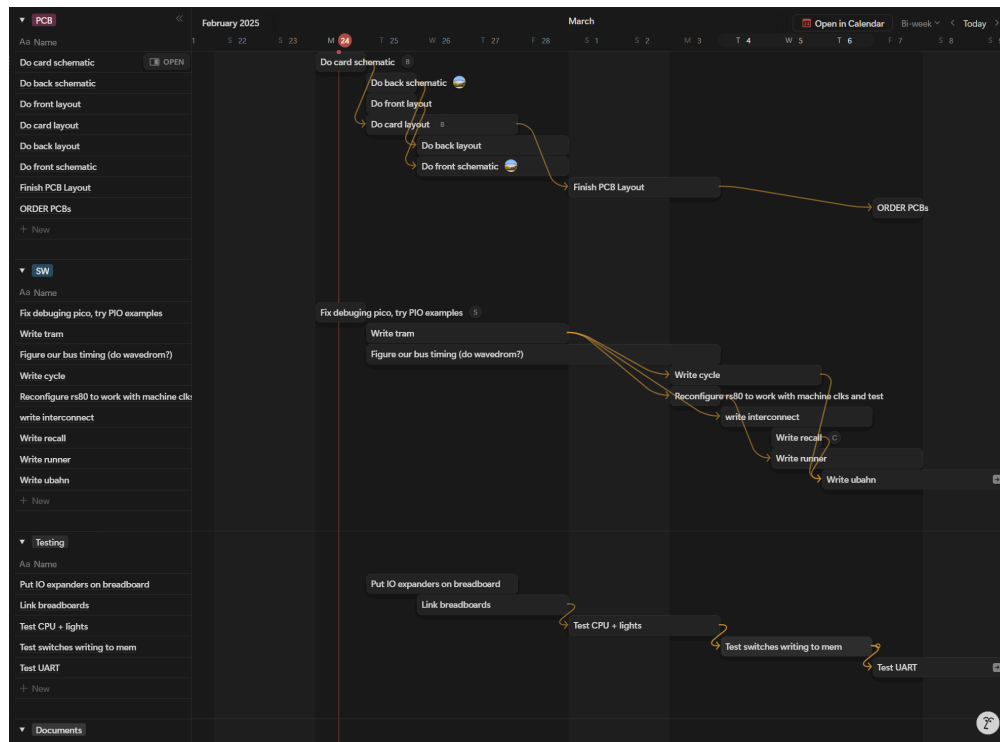


2/24, Monday

9:30am-12:30am

3 hours

First I created a notion timeline view in order to track all of our tasks that are remaining in the semester to complete our project and remain on time. Prior to this we all had an "idea" in our head what needed to get done and when and Brian was "confident" that we could get the project done in time. This didn't sit well with me, so i created a timeline and list of all tasks we need to do. Here it is:



Here is the link to our todo: [Calendar](#)

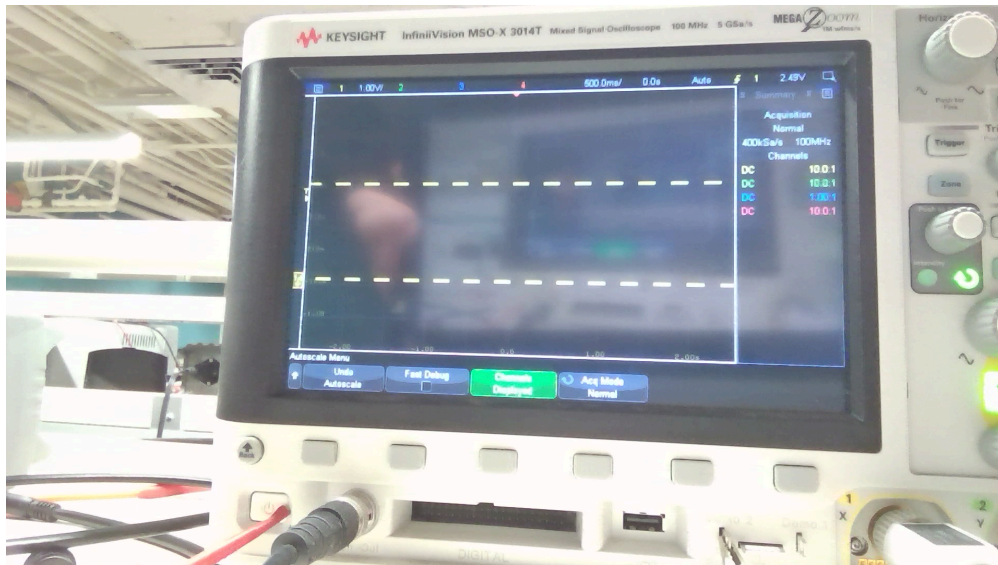
After the timeline I got started on researching the bus signals

In the meantime I explained to caleb how our sw packages are going to work together and how to flash the rp2350. I also created the interchange package (package for our front board).

Now i'm switching over to fixing the flashing for one of our microcontrollers. it wasn't working last time i checked. it could connect but not flash.

Ok got it to flash again. Also sometimes the device is locked so i need to hit reset before programming it.

Here is PIO based blinky working! so we know the pio works and how we can use it to send signals using Rust



Verified that the PIO blinky works the same on both of our boards.

Next I verified that the PIO R/W blinky works. Then I'm going to transform this program to run on one stamp ouputting and recieving on another to simulate a bus.

Next step though is to test UART as I think that will be an easier cross-communication example to setup than a full transactional PIO bus.

## Entry 1

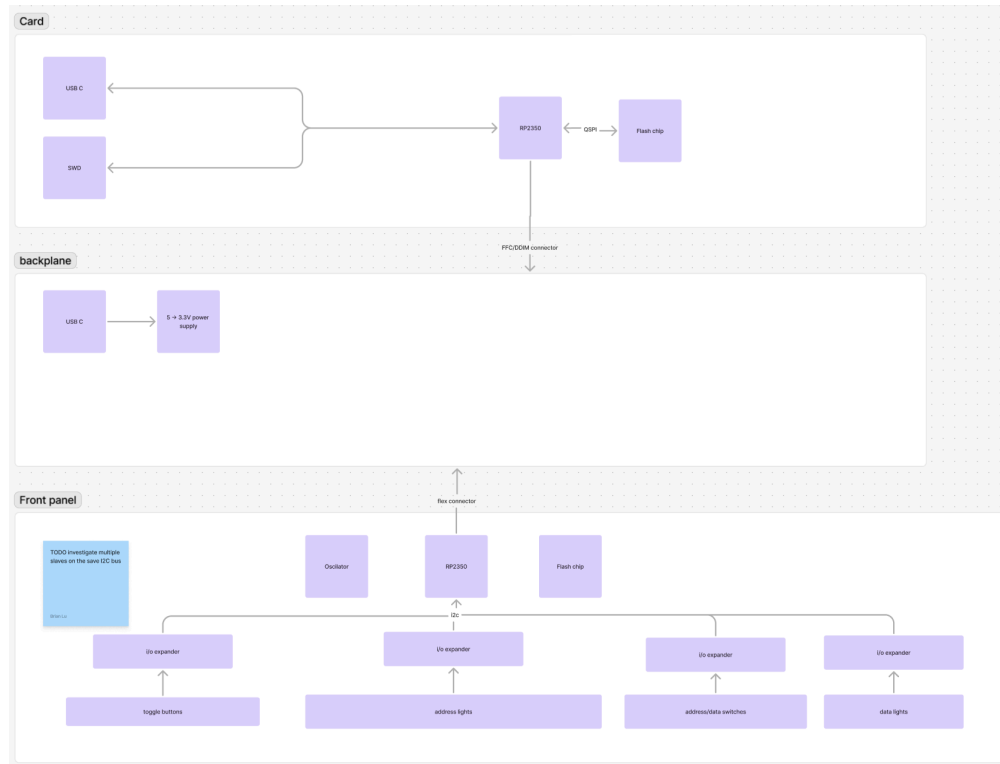
2/22, Sunday

12:00 am

2 hours

Today I talked with brian about our general software and hardware stack since I was writing A8.

We clarified how we were going to do the software layout and exactly connect the packages we made to link the bus with the card-specific packages. While doing this I got clarification on the hardware we are using and decided to make a Figjam diagram showing our layout from a top down level as this would help everyone in the team know the components or our project and interconnects:



Link: <https://www.figma.com/board/mlreLoKpSHAxYEdUPpXdqf/CASS?node-id=0-1&t=44ofTralHgVXlb8m-1>

I then added this to our website for reference as well.

I finished drafting A8 with making a testing plan with Brian. We are going to focus on making and testing tram, our bus package first, and then all other cards later. E2E tests are the most important for us.

## Week 6

### Entry 4

2/21, Friday

3 hours

trying to understand microcontrollers and gpio again. I don't remember anything from 362 🤔.

I used this resource to do so: <https://embeddedartistry.com/blog/2018/06/04/demystifying-microcontroller-gpio-settings/>

Push/pull:

- Inputs params
  - Pull down: default input 0 and connected to VDD
  - Pull down: default input 1 and connected to GND
- Output params
  - Push/pull: pin drives high or low
  - Open drain. Normally pulls low but usually you pull high so the line is always high and when a signal writes to the bus like with i2c (pulling it down), all the devices on the line pull down.

So relearned i2c so can get an idea how s100 bus works. <https://www.circuitbasics.com/basics-of-the-i2c-communication-protocol/>

—

I learned from brian that our addr line always asserted by CPU, so we don't need pull up resistors.

dedicated functions like i2c and uart exist for gpio pins because they are high speed and can't be done in sw like bit banging. our bus is probably going to be lower speed then. pio can help too of course

—

Learned about the ahb crossbar from ChatGPT. allows multiple peripherals to talk to cores at the same time.

Also asked chatgpt about mutexes and hardware spinlocks. Our microcontroller has 2 cpus, and uses these cross-cpu communication channels to manage access to shared resources. We likely won't need these for our project as our entire program can likely run on one CPU, but it's good to learn this and know what it is capable of. This microcontroller has a lot more features than the STM32 we used in 362.

—

Reviewed how AHB busses work because I want to know how multi-master buses work inside of the microcontroller and how they compare to busses we implement outside of the microcontroller.

This made me review how we did in 337. I referenced the AMBA guide:

[https://www.eecs.umich.edu/courses/eecs373/readings/ARM\\_IHI0033A\\_AMBA\\_AHB-Lite\\_SPEC.pdf](https://www.eecs.umich.edu/courses/eecs373/readings/ARM_IHI0033A_AMBA_AHB-Lite_SPEC.pdf)

Then I realized PIO is a thing and that we aren't going to be bit banging like I had planned to do to test out a basic bus connection between the two microcontrollers. So to learn about PIO, I watched this video which introduced PIO:

[https://www.youtube.com/watch?v=yYnQYF\\_Xa8g](https://www.youtube.com/watch?v=yYnQYF_Xa8g)

I learned all of the basic PIO configuration options for the GPIO and the mini instruction set the PIO blocks have as well.

Finally, I went back to reading the rp2350 datasheet and began reading about all the GPIO functions available on each pin and the registers that configured them.

This will help me understand how to configure the gpio pins for the actual bus (like pull down, open drain, etc)

Next steps are to continue reading through the rest of the microcontroller datasheet, and read and implement the PIO examples so that I can get the basic bus working.

## Entry 3

2/19 weds

1 hour

10am

Today I needed to figure out why the probe-rs debugger session was not highlighting lines when I added breakpoints and it stopped on them.

I retried debugging restarting vscode but still didn't work. I then tried debugging with python and saw it works fine. idk why it doesn't work with my c or rust projects. I leave it as it is. I'm still able to know what line it is by clicking on the sidebar so I should be fine.

The highlights were to help me debug faster and see the registers. Next steps are to implement the code for the bus and use debugging to make sure signals are being asserted and received.

## Entry 2

2/19 weds

3 hours

I worked with brian to get the pico debugger working.

We tried doing debugging using OpenOCD vs probe-rs which we were trying before and the pico could not find the device still.

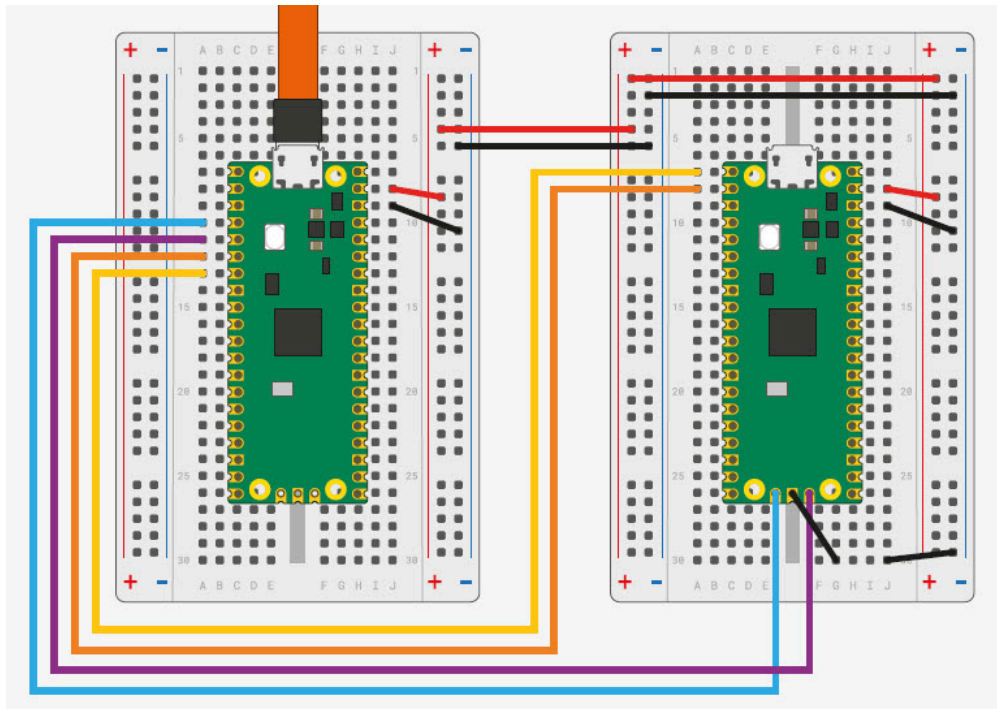
I tried connecting the pico to the stamp by connecting the swd clk and io and gnd pins from both, however the pico could not find the device.

We then tried monitoring the pico signals on an oscilloscope so that we knew it was sending data. That's when I realized we might not have the right pins being used.

I then looked up how to use the pico as a debugger and I found this guide:

<https://mcuoneclipse.com/2022/09/17/picoprobe-using-the-raspberry-pi-pico-as-debug-probe/>

I saw we need to wire the pico this way to act as a debugger



After rerouting the wires it worked for a bit but then stopped. We needed to readjust the contact between the jumper wires and the board so we soldered the jumper cables to the stamp. This made sure the contact was good. We tested the contact was secure using the multimeter conduction test.

Below is the completed setup



Next steps are to jumper all of the pins together to setup an actual bus between the microcontrollers and then write and test the bus code.

## Entry 1

2/17 mon

3 hours

Stamp boards got finished this weekend so I want to start programming and using them instead of the pico. I first explored the stamp schematic to see what pins and stuff were available. There was usb device/host.

I then plugged in the stamp into my computer. I noticed the default things available were a circuitpy thing. I saw circuitpy is a python library you can use to program stuff and the stamp xl carrier board is a supported board for the library.

I just wanted to flash a [simple blinky program](#) and use one of the LEDs on the board. I saw one LED was available on the Stamp XL board however this just seems to be an indicator LED and not one attached to a GPIO. Then I looked at the pins for the carrier board and saw an LED was available over GPIO 3. So I loaded up my rust RP2350 blinky project and changed the LED pin to GPIO 3 and flashed it holding the boot button. It worked!

Now I'm looking at how to use one carrier + stamp as a debugger, and the other as the board to be flashed. or i could use the pico we have as a debugger. I might do that instead since we want to use each board as ones with programs in the future.

ChatGPT pointed me to using the raspi debug firmware which is usually flashed to the raspi debug probe:  
<https://www.raspberrypi.com/documentation/microcontrollers/debug-probe.html>

I saw how the debug probe has UART for serial debugging like printf and then swd for actual debugging breakpoints and stuff with gdb. I also saw that openocd is what it recommends as a debugger, however I'm going to use probe-rs. I recalled probe-rs didn't support the rp2350 chips yet, however I checked again and the [latest release does!](#)

I got probe-rs up and running and it recognizes the debugger loaded on the pico! However, when I tried to flash the program from my computer over the debugger to our microcontroller, it said it couldn't find the board. So I need to fix this later so that we can flash over SWD.

This debugging capability will allow us to flash programs faster than usb and thus develop faster.

Next steps are to fix this connection issue.

## Week 5

### Entry 5

**Date:** February 14

**Start Time:** 1:30pm

**Duration:** 1 hour

Today instead of getting embassy to work, I went back to researching on how to implement the emulator because I now get how to implement the CPU. You can make the CPU a struct with methods like step(instruction) that will parse the instruction, and modify the registers/execute memory transactions based on the instruction.

Now that I knew this, I then looked through the [Intel 8080 datasheet](#) again to look at how the opcodes for each instruction are formatted. As I read, I realized that the opcodes were actually the same for multiple different instructions and that only register values of a different arrangement of bits differentiated them. 8080i is not like RISC-V where the opcode is the entire instruction. This means that I will need to write a parser that will take the opcode and the register values and determine what instruction to execute based on the opcode and the register values.

After understanding this, I then looked at the [rs80 emulator](#) again to see how he implemented parsing the instructions. He had a custom txt file format that stored all the instructions and their format and what rust code to execute for them. This txt file was then ingested by a separate package from the emulator that was responsible for code genning all of Rust code to handle the instructions. As he notes in his documentation, there are "256 possible 8-bit opcodes. Instead, the input file contains 59 instruction definitions which are processed and specialized." This is a great approach and probably what we should do for our project. In fact, how he implemented the emulator is exactly what we should do for our project so I then freaked out a bit how we could possibly make our emulator different.

After talking with Brian, Brian reminded me that the rs80 emulator did not handle memory wait, waiting for actual memory to respond and that in our emulator we would need to do that.

Therefore, I came up with my next steps which will be:

- I think I'm just going to get the Emulator programming on the Pi
- Run and hook up the RS80 simulator to our embedded code
- Simulate bus signals on the GPIO pins
- Hook it up to the pins and LEDs on the board
- Then use the IO expander we have to expand the signals like we will do on our final board.
- Modify the rs80 code to handle memory waiting stages so that it is machine-cycle based and not instruction-cycle based.

And that's our software development plan!

## Entry 4

**Date: February 12**

**Start Time: 12:30pm**

**Duration: 1 hours**

As a continuation of this time on the 12th, I asked ChatGPT a variety of questions about RTOSes and how interrupts/allocating CPU time between processes work to better understand how process switching works in operating systems. This wasn't exactly relevant to our project, however it gave me a better perspective on how interrupts work and when they are executed so I knew their difference with classic polling loops. For this reason I think we will do interrupts to step through/run/stop the CPU.

### Thy questions/answers:

does px4 autopilot use an rtos when it runs on a pixhawk? yes nuxtt os

what happens between when a person clicks a button on a keyboard and the program receives it on linux? what syscalls or whatever are involved? x11/wayland, can use poll, read syscalls. poll freezes execution of a program. can spawn multiple threads to wait for things in an os.

can you manipulate cpu time, the scheduling method, etc. in linux? yes cgroups

can you change scheduling type in windows? kinda ya you can set priority

can i see the list of processes and their ids in linux? ya

what does %cpu usage mean in task manager technically? isn't the cpu technically running at 100% most of the time because it's running monitoring loops? it's the percent of time the cpu is active with user requests. most programs just wait for interrupts triggered from syscalls to resume execution. they don't need to run 24/7. only if you make a while (1) loop will it run 24/7.

what's the diff between processes, subprocesses, and ids in windows task manager cpu. ids mean all threads

does rust have a callback queue/event loop like js? no it just spawns threaded runtimes

when you write a driver for linux do you interact with syscalls?

are syscalls the only interface/api to a kernel? no you use kernel space interfaces. kernel interface links hardware to os. syscalls link



os to program. open() syscall will call the open function defined in the driver. same with read() write().

#### END Q/A

Finally I learned about memory ICs and browsed digikey on how to find them. I later learned Brian had already selected one, however this gave me the opportunity to understand what was available out there, the sizes of memory ICs, and the different protocols they used.

My next steps will be to try to get the embassy crate to work with our Pico repository so that we can program our microcontroller with Rust using that.

## Entry 3

**Date: February 12**

**Start Time: 10am**

**Duration: 2.5 hours**

Today because I now shifted my focus from coding to emulator to coding for the microcontroller, I decided to create a new package in our main Rust repository dedicated to just programming the Pico. I did this instead of just starting on a Rust repo because the Pico was just our development board and was not going to have the same layout/interface/board abstraction layer as our final board design. I then added the cargo dependencies from the example [RP2350 example repository](#) that I used previously to first program the RP2350 with Rust. I ran into some missing linker files which I added from the original repo to mine, however even after adding those I ran into other linker errors that did not relate to missing files. This is the one I got stuck on:

```
rust-ld: error: undefined symbol: _critical_section_1_0_release'
```

I think it got stuck because the rp235x-hal package is not correctly built for the version that is published on Cargo.

I was unable to fix this so instead of trying to further debug how to get the rp235x-hal package to work, I researched again if any other Raspberry Pi microcontroller HAL cargo crates existed. I came across this [Rust on the RP2350 blog post again](#) and in addition to mentioning the rp-rs project that publishes the rp235x-hal, they also mentioned another project called [Embassy](#).

I looked at Embassy's website and realized it had the unique property of async/await which I was familiar with Javascript. I used ChatGPT to help me understand how async/await worked in Rust vs how it did in Javascript. I learned that in Rust, async/await is compiled to a bunch of state machines and the order of execution/waiting hands idle time over to following instructions. I also learned the difference between concurrent and cooperative running. I also learned what rust runtimes like tokio do. Finally, I learned what RTOSes do and how they differ from regular operating systems. I did this because the Embassy project noted that it was a faster alternative to traditional Real Time Operating Systems at the cost of maybe more code. RTOSes are more lightweight than traditional operating systems and directly use interrupts to handle events and poll for new event priorities maybe every 5 or so instructions vs time-based CPU slicing which traditional OSes do.

This was all of interest to our project because I wanted to know if async/await or RTOS would be a better/easier implementation for our emulator/microcontroller over standard interrupts/polling loop. I determined async/await would be okay and that we could proceed with embassy.

## Entry 2

**Date: February 10**

**Start Time: 10am**

**Duration: 2.5 hours**

Today I focused on beginning writing the emulator because I thought that would be easier than starting directly on the embedded interface code. Because I have not coded in Rust a while, I needed to review data structures so that I

knew how to implement the data structures to hold the registers for the emulated CPU and methods to perform operations on the CPU. I began going through the beginning of the [Rust Book](#) again. I recalled how structs, enums, mutability, ownership, and implements work. These functions of the language should be enough for me to be able to program the emulator.

I also realized when beginning to write the emulator that we would need separate code for our memory card that was to also operate on a clock cycle and send signals from our bus on the GPIO pins over SPI to a memory module on our memory board. Because of this I started another Rust package in our workspace for the memory and drafted memory get/receive methods.

Midway through drafting the architecture, I got confused how our Rust package for the emulator was going to react to clock signals. I thought implementing the code needed for our microcontroller from the top down (GPIO signals first, emulator second) would help clear this up.

Now that I switched to thinking about how the emulator would handle clock signals, I was researching whether we should use just an infinite loop to poll for external clock signals or create interrupt functions. This led me to do more research on their differences and review what actually happens during an interrupt routine as we learned in 362.

I ran out of the time for the day so I decided to leave this research of interrupts vs loop for the next day.

## Entry 1

**Date: Feb 8**

**Start Time: 9:30**

**Duration: 1 hour**

Today I focused on debugging why the pico was not flashing with [example Rust-based code](#).

I was trying to flash it using the elf2uf2-rs tool, however, I found a Github issue that said the elf2uf2-rs tool cannot flash the RP2350 yet and that I should use picotool instead. So I downloaded picotool and changed what tool was being used to flash in the `.cargo/config.toml` file and ran `cargo run --target thumbv8m.main-none-eabi` and it worked!

What's annoying is that you have to unplug and replug the USB every time and hold the BOOTSEL button when flashing in order to get it into flashing mode for UF2. However, once it flashes, the program runs immediately.

Now that we can program the microcontroller with Rust, we can begin writing the Rust code to listen to bus signals on the GPIO pins as well as begin integrating it with basic emulator code to say enter instructions with switches and trigger a clock signal with the push of a button. That will be my next step.

## Week 4

### Entry 3

**Date: February 7th**

**Start Time: 9:30am**

**Duration: 4 hours**

First I updated our PSDRs and functional description based on weekly feedback.

Then I got to trying to figure out how to flash the pico with our Rust project code. I compiled the Pico code successfully using cargo and tried to flash using `cargo run` but that failed. I saw it was trying to use [probe-rs](#) which I thought I had installed, but it looks like I did not because the command was not available. I then installed it and tried running it again but it said no probes could be found. I then realized probe-rs is only meant to work with a dedicated/separate debugger and I would need a dedicated debugger like another Pico or ST-Link in order to use it to flash our Pico.

So because I did not have another debugger on hand, I found in the flasshing methods section of the repo that you can flash in other ways like UF2.

UF2 allows you to just upload a UF2 file to the pico over its USB file system which is triggered when you hold down the boot select. I was able to do that and it programmed sucessfully.

A debugger will be useful in the future, so I've decided I'll bring my st-link from 270 and hook it up to the SWD lines on the pico to try debugging it.

Finally I needed to work on A5 and write the justification for why we chose the RP2350 microcontroller. As part of this process, I realized I didn't have a good grasp on Program IO so I read [this article](#) on how it works and how it can be programmed. I then consulted the RP2350 datasheet to further learn how PIO is supposed to be used.

## Entry 2

**Date: Februrary 5th**

**Start Time: 10am**

**Duration: 3 hours**

First I worked with Nathan on getting the raspi pico that we had on hand programmed.

First I tried following the [raspi pico getting started manual](#) and using the VSCode extension, but I was unable to get the toolchain to download on my computer. So then I had nathan do it and he was able to get it to download and flash.

Next I got started on figuring out how to setup an embedded Rust project and program our Pico with it.

I first created a rust package for "cycle", our emulator, which I wanted to run first. When creating this, I had to learn about cargo and the difference between workspaces and packages. I decided to make our emulator just a package in our monorepo since it may link with other things in the future.

Finally I needed to figure out how to use the repos in the rp-rs org to program embedded rust for our microcontroller. I came across this starter project template <https://github.com/rp-rs/rp2040-project-template>

I also needed to learn the terms of the other types of repos in the github org like HAL, which is hardware abstraction layer, and PAC which is Peripheral Access Crate. These are the handy APIs/interfaces for manipulating our microcontroller with rust without having to change registers and stuff.

## Entry 1

**Date: Februrary 3rd**

**Start Time: 10:15am**

**Duration: 1 hour**

First I watch [how a microcontroller starts video](#) to learn how the boot process of the program we flash is set up and how the [Rust based flasher](#) we are using will do it as well.

Next I did a bit of reading of the [embedded rust book](#), learning about how embedded rust code typically looks and what data structures/coventions we can expect.

Next I got into a bit of a read about posix/cygwin cause I noticed embedded rust code can run on a [variety of environments](#) like bare metal vs. hosted. We will probably only need bare metal for our project.

Finally I looked back into how platformio works since I was wondering if it supported Rust-based microcontroller development. I needed an easy way to get started with the pico we had lying around and I knew platformio was mostly C programming so I anticipated it was not available yet and I was correct. So we're going to have to stick with [rp-rs](#).

## Week 3

### Entry 4

**Date:** January 31st

**Start Time:** 9:30am

**Duration:** 3 hours

Today I needed to figure out how to convert the Intel hex to binary. ChatGPT pointed me to just writing a simple Rust program to this which I tried.

I realized that I need to place it in a specific part of the repository like as a binary to make the rust compiler happy because the folder I was putting it into was a cargo project and all Rust files in a project either need to be a library or a binary.

I then did ChatGPT's second suggestion of using the `srec\_cat` command line utility to compile the hex to binary. I was confused how to get this CLI tool until I learned more how Debian packages work since I'm working on Debian. I took a little bit of a sidetrack into learning about Debian packages.

I learned that packages can have the same name in different repositories (debian, debian-updates, debian-security) and the package manager will choose the package with the highest version when upgrading

I also learned about supported architectures for debian and that the official ones, powerpc, arm variants, x86 64 and 32, ibmz all the packages are supported.

So all the packages must be compiled to run on those architectures and the maintainers of distros handle upgrading packages, not the package maintainers.

And then you can have multiple versions of a package on a system and apps on a system can point to different versions of a package they need since they are dynamically linked. And then finally, Rust packages try to all be statically linked (all in the binary) but debian maintainers don't like that so they try to break up the packages.

Although this was a bit sidetracked, this helped me learn about the packaging ecosystem and how Rust works with it. It helped me tie my knowledge about dynamically linked libraries learned in OS right now to my work of how we are going to program and link our programs on our microcontroller.

I then got the actual package name for `srec\_cat`, [Srecord](#), and tried converting the hex, but didn't have luck. It seemed like that the assembler was not happy with my output and the assembler was not happy what I loaded into memory and tried to step over the instructions. I wasn't fully confident why it wasn't stepping correctly and also wondered how the processor knows it's on an opcode vs value vs register/address. I need to save that for next time.

Since I now have a good idea of how the entire repository works, I diverted my attention to getting our own repository setup. However, I realized that I didn't know really how to start and how our emulator was going to interface with the microcontroller itself and not just a human user through a terminal like the emulator in the rs80 project.

This led me beginning my research into embedded Rust. First I looked through the repositories that Brian had linked that are part of the [rp-rs organization](#) that has developed tools to program RP-series microcontrollers with Rust. However, I realized I didn't know exactly what most of the repositories did and that I need more of a getting started guide.

I then looked up some embedded Rust resources. I came across this [How to Do Embedded Development with Rust](#) which I began watching. Also began watching this [How a Microcontroller starts](#) video because I want to get an idea how the Rust framework programs the microcontroller and how memory is laid out on a Microcontroller. Finally I found this [Rust on RP2350 - Raspberry Pi blog post](#) which I will save for later.

The progress today has opened my research up to jumping into embedded Rust and getting started on our software development. I'm excited to learn how to write type-safe code for our microcontroller and how to interface with the hardware. Next steps are to finish getting through those above resources and begin coding!

**Date: January 29th**

## Entry 3

**Start Time: 9:30am**

**Duration: 2.5 hours**

I wasn't able to find the registers available in the original [8080 manual](#) for computations so I found this additional [cheat sheet](#). We could even make our own cheat sheet that is a bit more understandable like this [RISC-V one](#) so that future people can more easily program for our emulator.

After understanding all instructions available for the 8080, I then went back to investigating how to run the [rs80 8080 emulator Rust repository](#). I found that these compiled binaries were available:

mon: a debugger that allows you to read and write to registers and load a file into memory and jump to address and then exec

asm: assembler that take 8080 instructions and turns them into

8080 ones doesn't seem to work well though rn with MOV A, M just as text in an input .asm file. Uses the [CP/M ASM compiler](#). The emulator actually spawns the original CP/M compiler on the emulator itself to compile the assembly code you provide on the host system and then spit it back out. I found the manual for the CP/M assembler here which gave me a better idea of its output and how to use it.

disasm: Just a disassembler

main.rs: A main runtime for the emulator for which you are supposed to provide an OS image like CP/M to execute.

From this research I determined that we will need an assembler like CP/M in order to convert our 8080 code to binary.

I also realized that the assembler only spits out Intel Hex and that the intel hex cannot just be inserted into memory using the mon debugger. Intel Hex != binary. Only part of the intel hex is the binary we need, and we need to convert the hex to binary using some tool.

Finally I learned about the tests folder that contains various test .COM (executable 8080 binary) images that are used to verify the emulator properly exeecutes all available 8080 instructions. We should incorporate such tests into our emuator as well.

I will save the rest of converting the intel hex to 8080 for friday. This progress today got me closer to my goal to running the rs80 repo.

## Entry 2

**Date: January 28th**

**Start Time: 7:15pm**

**Duration: 0.75 hours**

During this time I attempted to get the [rs80 8080 emulator Rust repository](#) created by cbiffle on GitHub running. I di this so that I can get an idea of how we can structure our own implementation of a repository and how to construct a Rust project since I don't have really any experience using Rust.

To understand how to run the repository, I utilized GitHub Copilot to look at the repository for me and give me an idea of what its contents, produced binaries, and available commands were.

I then realized I didn't have a good foundation of what the 8080 instruction set looked like so I didn't know how I could write an assembly program to run on the rs80 emulator.

I then began reading the [8080 ISA datasheet](#). I just read through the first few pages and during this time I determined how the two different clocks of the 8080 work, what cycles and states are, and read through the instruction set. I

then learned that opcodes are 8 bits which take up the entire processor bus (8 bits) so it takes multiple states to execute one instruction, contrary to say RISC-V. Learning this helped me understand how I would write our own emulator to process instructions and that we don't need to emulate the entire functionality of the 8080, just be able to process the instructions according to external bus signals.

Next steps will be to continue reading the manual since I didn't get through all the instructions available.

## Entry 1

**Date: January 27th**

**Start Time: 9:30am**

**Duration: 2.5 hours**

I read through more of the [RP2350 datasheet](#).

I specifically read through the GPIO pins available and their functions. This was to determine what pins would be available to function as our S100 bus.

I then investigated the bus layout (2.1) and processor layout. This was to get an idea of how the microcontroller interfaced with its pins. Additionally how data was controlled between the RISC-V and Arm cores available and how we could use them if we wanted to choose one or the other.

Terms that I found in the document and used ChatGPT to learn about included the Always-On-Timer and Serial Wire Debug Input/Output.

Reasearching these terms helped me get a wholistic view of everything that was available with the microcontroller and how we could use it for our project.

I think I am well-versed in the overall capabilities of the microcontroller we are using. I'm now going to move onto researching how to code the emulator I and Caleb will be responsible for implementing since that is a more urgent task.

## Week 2

### Entry 2

**Date: January 24th**

**Start Time: 9:30am**

**Duration: 1.5 hours**

I discussed with brian how our computer would load programs

I learned that the front panel is basically useless because it doesn't allow for easy program input while the computer is running and is mostly for just programming the bootstrapper for the microsoft basic OS you were going to load into memory. Then all programming was done via the os on a monitor connected over the uart. could be teletype, etc.

So our computer is not that useful without uart and although it is a stretch goal it is one I want to achieve.

We would want to connect our computer over uart and open a serial console to interface with it.

I also determined with the team that we are going full rust and not programming the 8080 with C. Based on this rust implementation of the 8080 it's not that much to establish the data structures to get the state machines for the processor. I was concerned that because rust has a high learning curve and Caleb who was working on the software with me might struggle, however we believe we have enough time to learn rust and program the 8080 emulator in the semester.

## Entry 1

**Date:** January 22th

**Start Time:** 9:30am

**Duration:** 2.5 hours

Today I went through the [RP2350 datasheet](#) today (1.5 hours). Learned about how programmable i/o works using ChatGPT (what we're going to use for our bus) and why we're choosing it for our microcontroller vs. others (discussed with brian).

I attended project discussion/group meeting (0.5 hours)

Looked through the code of the [Rust 8080 emulator repository](#). we were looking at that was similar to what we wanted to implement. Determined that we could use this as a test suite to check our hardware if we don't finish our own emulator before.

## Week 1

### Entry 2

**Date:** January 17th

**Start Time:** 9:30am

**Duration:** 2 hours

I wrote the functional description on the a1 doc as well as drafted the budget

I made and reviewed project milestones with the team

I uploaded bio to website and functional description

### Entry 1

**Date:** January 15th

**Start Time:** 8:00am

**Duration:** 3.5 hours

Before lab I learned about the s100 bus today, researched the 8080 instruction set, and watch some altair 8080 programming videos

Then in lab we learned about the lab resources and introduced our team

I then discussed with brian and team what case we want (extruded aluminum) where the pcb slides in on one of the ledges. What box we choose determines our PCB size

Then we discussed what project management software. microsoft planner, notion, github issues?



I got the Github org setup with the name Alpha Cassiopeiae