TM7 notes (2023·1·4)

TM7 prototype finished production. Yet to arrive.

TM7 dev log recorded in little blue book. Here's a summary:

41.9 x 41.9 mm, 22mm NATO strap

Twin I2C 4-digit LCDs, 8 digits total + Twin RGB backlights
5 auxilliary LEDS
Central rotary "cooker" knob, 16 pos
4 tact switches, 2 flanking each side of cooker

SAMD21G17A : 48MHz 128Kb flash, 16Kb RAM

CR2032 coin cell battery ≈ 220mAh
LIR2032 LiPo coin cell battery ≈ 40mAh

piezo buzzer

Main features:
- 1/1000 sec chrono w/ tach
- Party mode
  Added 1/30/2023
- Maximum adjustability
  ↳ Energy profiles, Energy migration, sensor tweaking, sensor fail,
     dynamic frequency scaling, switchable strat (power) modes, etc.
- kick-ass design

2023.1.6   TM8 considerations

- USB
  ↳ micro USB cuz small footprint
- Debug port
  ↳ test pads for now, but need a more
     plug'n'play solution.
- Bomb ass livery
  ↳ "64" racing number? or save that for Dad

2023.1.7   TM8 plans cont. _____

- Debug port not possible. Stay with test pads
- Might ditch Ferrari livery
- Add I2C temp sensor
  ↳ will share ~~the~~ I2C line with LCD2.
     ↳ LCD2 might have to turn off when temp is
        in use.

2023.1.8   TM8 board updates _____
- added BMA400 I2C accelerometer.
  ↳ made necessary power connections, with I2C pullups too
  ↳ brought out SCL, SDA, INT1, INT2 as solder pads.
     - need to manually wire these later. Janky
        solution but should work.

BMA400:
< 14.5 uA at highest
0x14, 0x15 address
step counter, tap detection, run/walk detection

1/24/2023 hardware revision notes
- wired flood_left and flood_right to PA10(TX), and
  PA05, respectively.
- Moved LED3 to PA06, was originally PA09.
- INT2 moved to PA03, was originally PA05.
- changed floodlights angle to vertical for better
  illumination angle
- aligned debug test pads for cleaner look. Matched
  angle to fender flare. RST still stuck in its place.
- Added resistors for floodlights.
- optimized routing and filled GND plane whenever possible.
- Thickened all power lines from 8 to 16 mils. Widened
  some non-power signals for aesthetics.
- moved/repositioned some parts around to make room for traces.

STDs:
☑ design cool livery
☒ start looking up hi-power white 1206 LEDS. RA-mount
☑ shorten signals for cooker. unnecessarily curvy
☑ possible USB-c? Check if port + passives fit
☑ clean up schematic. Label all parts with
   appropriate names and values.
☑ Enlarge solder pads for SWD, add more for I2C
                                    ↳ not done, will do
Completed 1/28/2023.
~~USB c~~ USB-c doesn't fit.

1/25/2023   Sensor notes

- LIS3DH
  - 3 modes: Normal, low power, power down.
    - Normal 50Hz: 11 μA
      Normal 1Hz: 2 μA
      LP: 6 μA
      PD: 0.5 μA
  - ±2, ±4, ±8, ±16 G dynamically selectable fullscale
  - 10-bit 32-level FIFO
  - Free-fall, tap, double tap, orientation detection
  - 3 auxilliary ADC, ADC3 hooked to temp. sensor. Accessible over I2C.
    - ADCs not wired as of 22:22 cuz of space constraints.
  - Self-test feature
- BME680
  - Temp opr. range −40°C — +85°C
    - Absolute accuracy ±0.5°C — ±1.0°C
    - Resolution 0.01°C
  - Pressure opr. range 300 hPa — 1100 hPa
    - relative acc. ±12 Pa, absolute acc. ±60 Pa
    - resolution 0.18 PA
  - Typical current consumption:
    - 2.1 μA to 18 mA normal
    - 0.15 μA sleep
  - Altitude ±1 m according to Adafruit. Probs not accurate.
- MAX17043
  - fuel gauge IC for single-cell Li-ion
  - Alert pin activates after programmable threshold
  - 50 ~ 75 μA active, 0.5 ~ 1 μA sleep

1/26/2023

STDS:

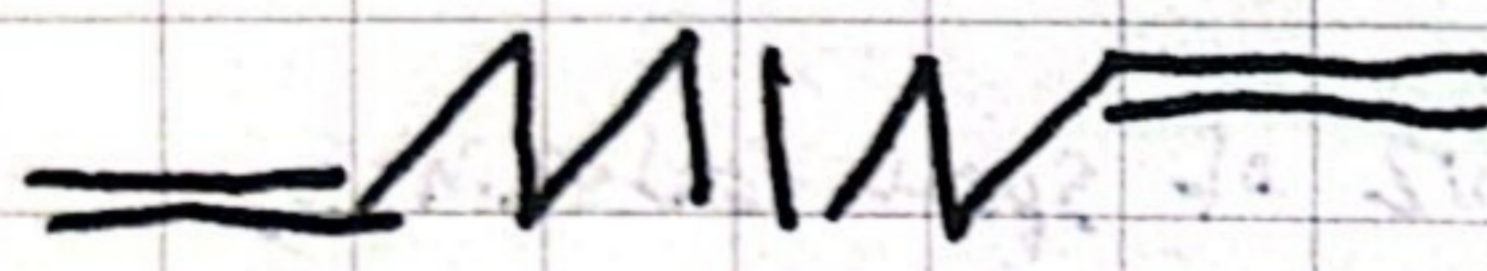☐ read up on sensor datasheets. Especially:
 ↳ LIS3DH interrupt pins and temp sensor
 ↳ low-power modes and self-test features

☐ read up on ASF I2C routines
 ↳ ask ChatGPT for help

1/27/2023 design notes

—∿MIN∿— → inspired by Carlos Sainz's 55 logo

≡∿MW≡

↳ somehow incorporate this into 16mil SCL & SDA lines
 on top side, right of the board?

1/28/2023 hardware revision
 1. cleaned up some traces. shortened signals for rotary
 2. enlarged SWD pads. RST +F, all others 16. Splayed 'em out
    more for easier soldering. 12
 3. pushed BME680 a bit to the edge.
 4. Designed sick exposed copper livery. Silkscreen ∿MW logo
 5. cleaned up schematic and named all components. Yet to
    add value tho.   6. moved FLASH_LEFT +3 from PA10(TX)
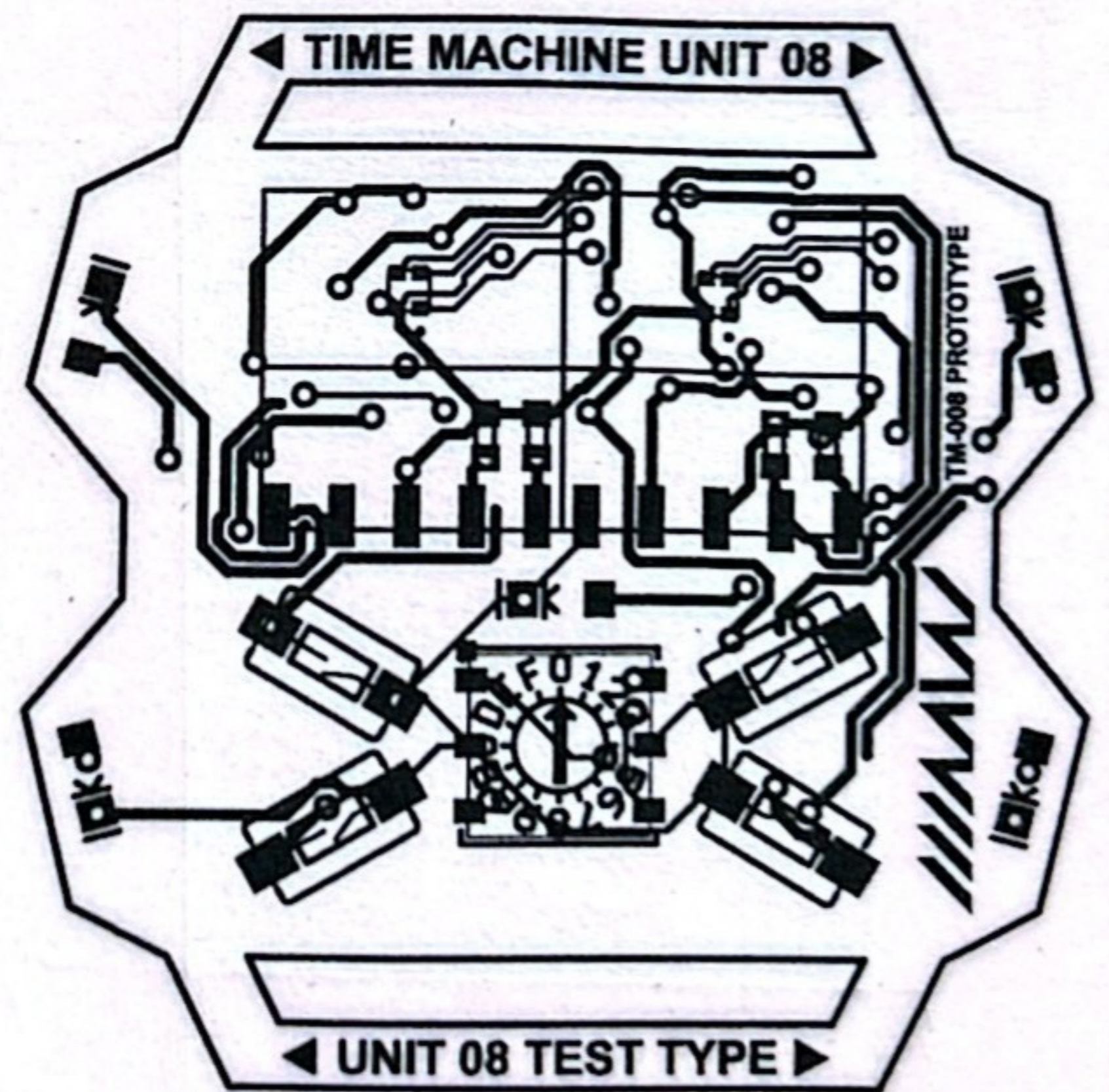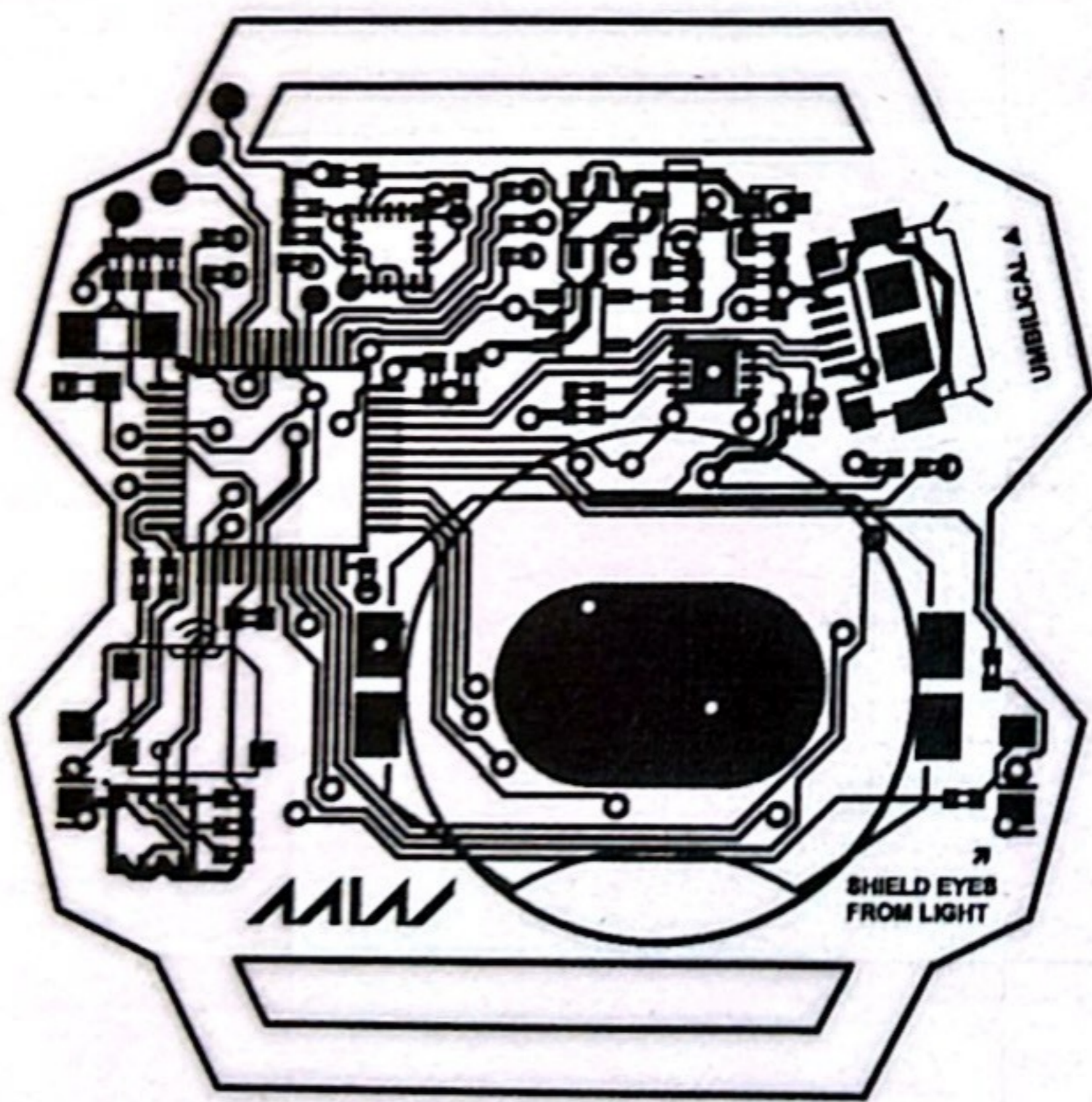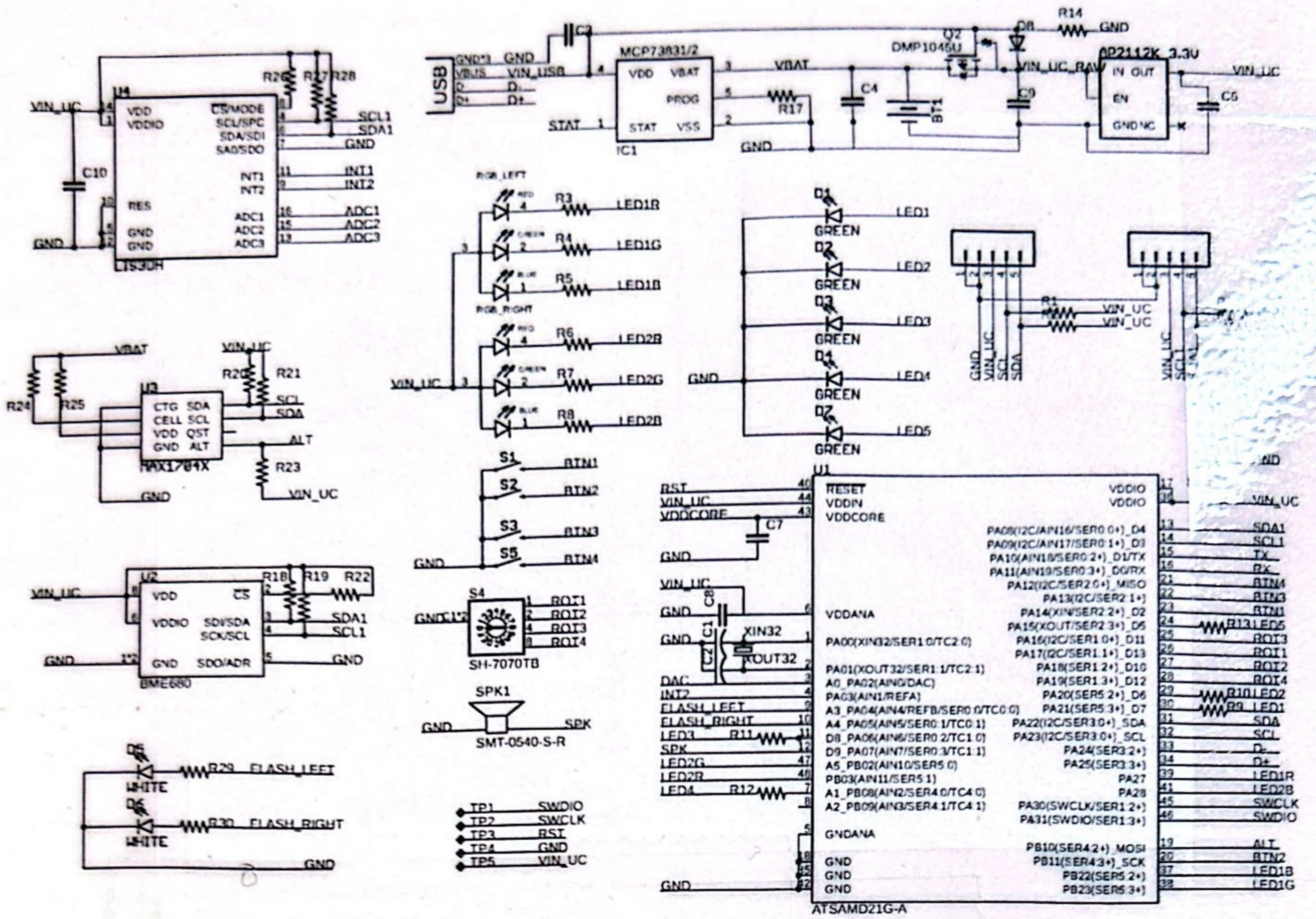   to PA04. Tx now free!
 STDS:
 ☑ add I2C pads on bottom
 ☑ check for collisions —→ checked 2/4. None.
 ☑ look through 80's fendered cars and find inspiration
   ↳ Seiras, 131 Abarth, Countach, etc. → no inspiration found.

TM8 Schematic, Back, Front (counterclockwise)
as of 1/29/2023 22:11
(Actual Size)

3/1/2023

— Replaced 5x5 0540 buzzer with 3x3mm 0340 package.
   ↳ Saves a bit of space, so decided to add another sensor.

    ↙

TWO OPTIONS:

1) MEMS Microphone
    ↳ useful for VU meters and flashy party mode stuff
    ↳ Maybe store short clips of sound and play it back?
        ↳ How much memory would that use?
        ↳ external flash probably required

2) IR reciever
    ↳ great for low-power cheap wireless comms
    ↳ control TM8 with a remote?
    ↳ Dock with wireless blaster. Simple Data transmission
        with IR, like setting time or importing lap times?

1) is cooler but 2) is easier to implement, more useful too ig

Swapped spaces between buzzer and BME680. Space left in
lower left corner for more stuff.

unrelated idea: report uptime in sitrep function
    ↳ is it even possible to keep track of operational uptime in deep sleep?

3/5/2023

Added TSOP 75X IR receiver to TM8.
Still far from perfect tho.
↳ IR receiver too big & tall. Find smaller replacement.
↳ too much wasted space. Clean up design!

3/6/2023

Cleaned up backside.
- cleaned up PSU circuitry.
- pushed BME680, buzzer, and IR receiver further inboard.
  ↳ removed one of the BME680's 0.1μF caps as it seemed
     unnecessary and a waste of space.
- rearranged floodlight resistors.
  ↳ swapped I/O pins for left floodlight and lower-left
     LED for easier and cleaner routing.
- cleaned up routing in general and filled in some previously
  empty ground planes.

Some potential issues tho:
→ buzzer fires out from the top. When watch is worn, the
  buzzer will be facing downwards, and sound might be
  muffled.
  ↳ move buzzer closer to outer edge where its top won't
     be blocked. See if IR receiver can lay flat, and not
     on its side.
→ 1μF cap connecting VDDANA to GND is too far away from
  μC. Move it closer! Cap is C8 on schematic.

3/7/2023 "EL PLAN"

revised because my vacation was blown. Next vacay
3/29 ~ 4/2. Crucial 5 days.

3/29 : Assemble TM7, at least 1. Assemble UCI. Blink test.
3/30 : Test all peripherals. Make another TM7. Test LCD fitment.
3/31 : Test clock scaling, port manipulation, sleep modes.
4/1 : Make "prototyping dock" thingy. Film short video?
4/2 : Final software tests and checks.
    ↳ Always be writing notes for stuff to fix on TM8!

IR receiver ideas:
— Docking station with IR blaster to wirelessly transmit
    small samples of data?
    ↳ No, a dock would be too big and unnecessary.
        ↳ what about a USB key with an IR blaster?

— IR blaster key
↳ Small USB stick with IR blaster and some buttons?
  ↳ can control TM8 directly from a PC via command line interface.
  ↳ Buttons for quick actions. Maybe a 7-seg display as well.
  ↳ Sync time with PC, sync cap data, party mode content, etc.

— IR control mode
↳ Connect TM8 to PC. TM8 acts as HID device and allows control
  of the PC via IR.
  ↳ music control, password keystroke injection, sleep/wake, etc.

3/8/2023 Ideas for TM9

Idea: "expansion board" stacks behind the back of TM9.
 "⌐" shape to go around battery.
 ↳ Battery is over 3.2mm thick, most components only around 1mm.

Connector : Molex Slimstack FPC connector
 ↳ probably 6 pos, maybe 8. will carry power + I2C and/or maybe SPI 👀?
 ↳ connector height (space between PCBs after connection) around 1.5mm ~ 2.0mm
 ↳ PCB thickness 0.8mm. It's the thinnest you can go w/out paying more.
 ↳ 1.5 + 0.8 = 2.3, still leaves about 1mm for parts on the expansion board.

Two possible ways to use this:

1) put only essentials on TM9. clock, caps/resistors, PSU. all other sensors/ICs go on expansion board
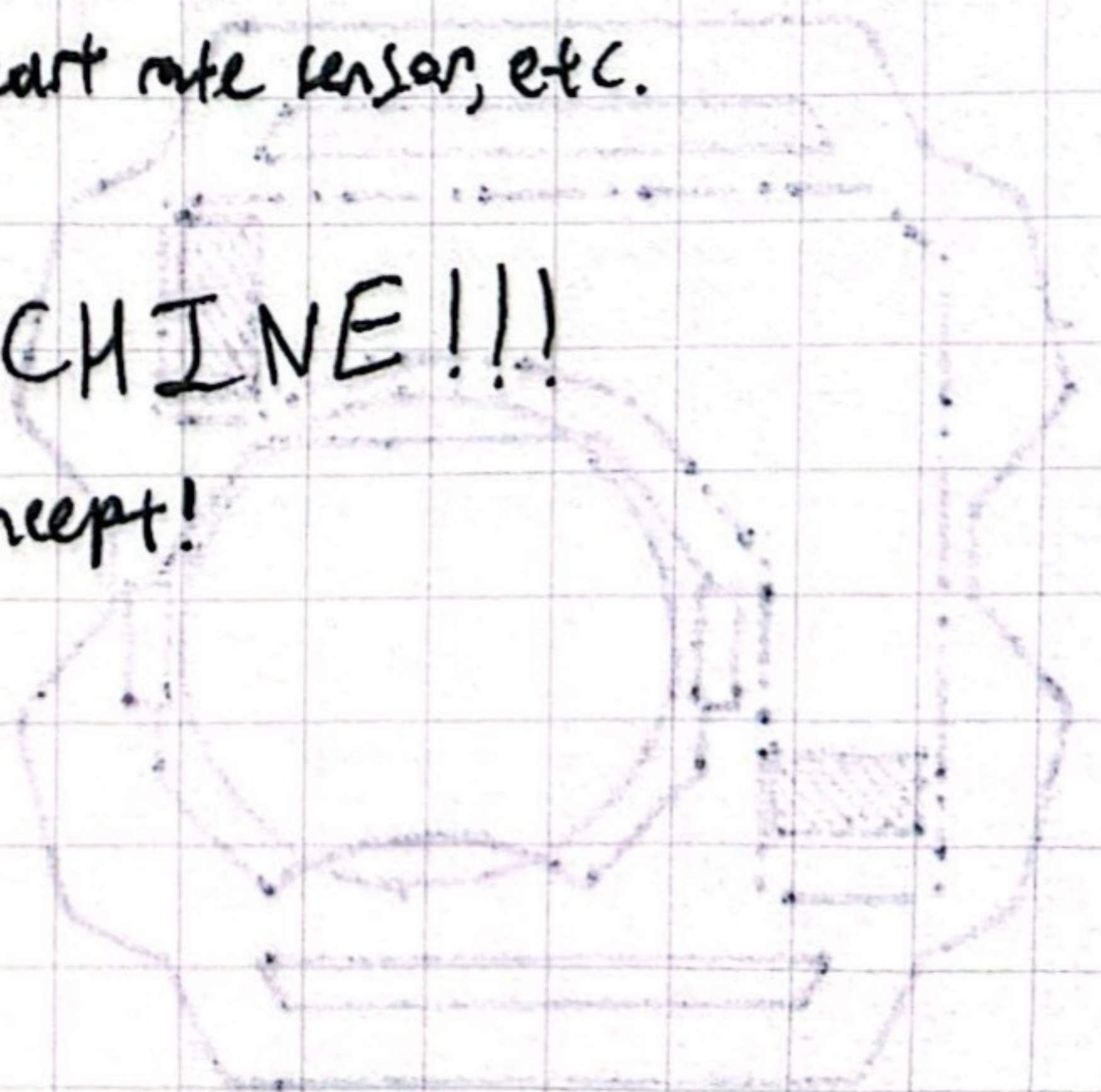
2) actually there's no other way.

 ↳ This will allow swappable sensor modules.
   ↳ IMU board, wireless board, heart rate sensor, etc.

MODULAR TIME MACHINE!!!
 ↳ let's keep chewing on this concept!

3/10/2023 More notes on expansion modules

Maybe I should upgrade to a 10-pin connector?
⮑ eyeballed dimensions 3.5 x 7mm.

Signals: GND, 3v3, Rx, Tx, SCL, SDA, SCL1, SDA1, MISO, MOSI, SCK
   + some more for connection detection, general I/O, etc.
   + ditch USB connector. replace with expansion connector
   ⮑ USB connector is big, thick, and will block expansion header area.
   ⮑ incorporate D+ and D- to exp. conn.
   ⮑ make "USB Dock" with PCB USB A plug for simple
       and easy connection to a PC. Maybe USB-C?
   + also incorporate SWD pins if possible.

PROS:
+ can move battery charging circuitry to dock.
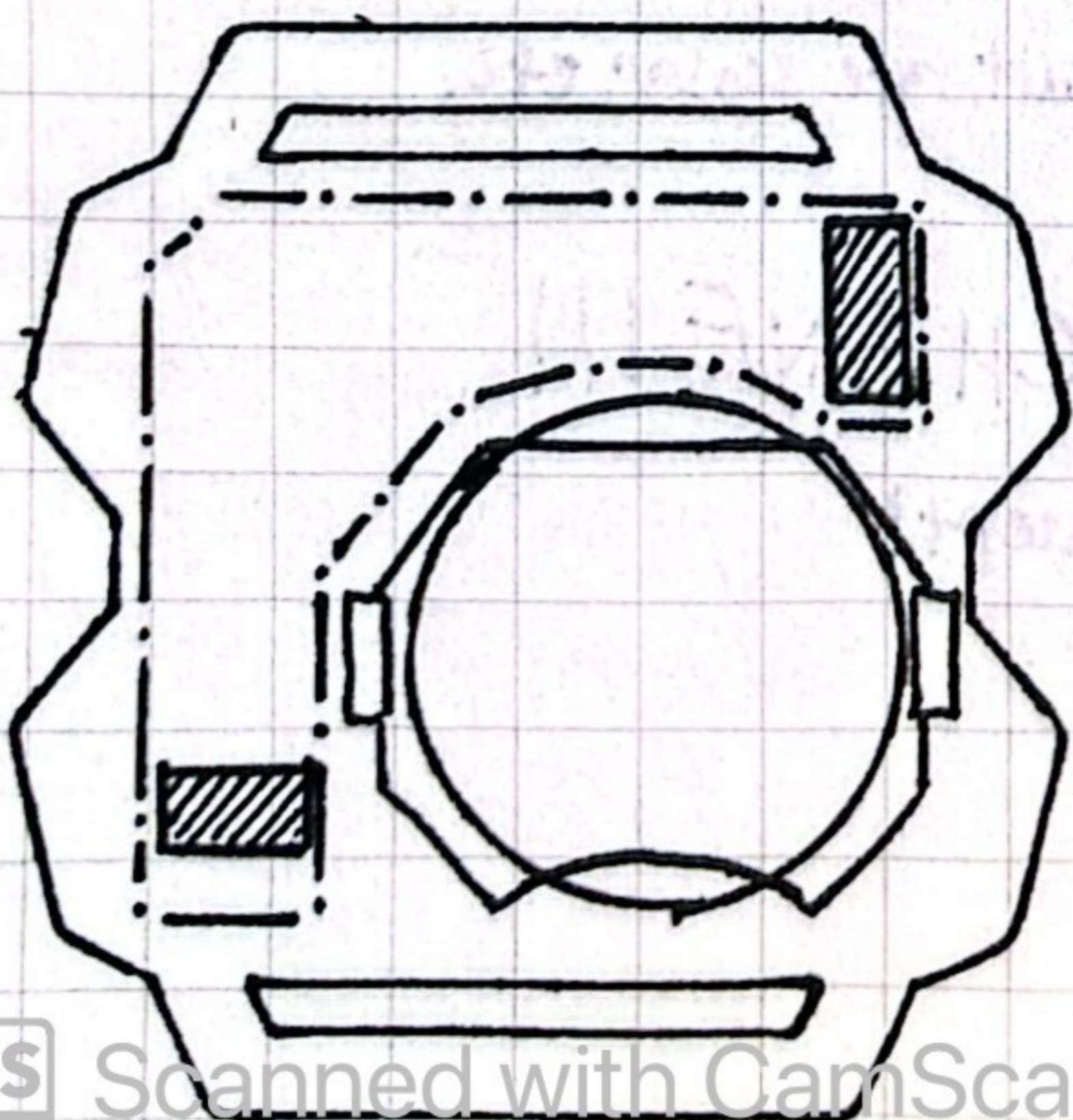+ modular! MASSIVE GAINS from this
+ significantly increases board area in the same volume
CONS:
- will probably kill USB. PC connection will require strap off.
- Mechanical integrity of connectors?
-

3/25/2023   Evaluating TM8 as a "resume"

What would potential employers like/dislike about TM8?

LIKE:
1. Hobby project. Shows passion, enthusiasm, ~~EE~~ work ethic, effort.
2. Foreign concepts (to me). Shows desire to learn.
3. Made in army. Shows I put my time to good use.
4. Low-energy optimized. Shows experience with low-power systems
5. PCB routing. Dense PCB, very small, 2 layers 8 mil max trace width
6. Comms protocol. USB, I2C, IR, SPI as well maybe?.
7. Embedded systems design/coding.
8. Basic EE. Bypass caps, routing guidelines, clocks, etc.
9. Firmware design, maaayyybe RTOS?
10. Unique design and implementation shows creativity and inspiration.

DISLIKE:
1. Took very long to make.
2. No dynamics. No motors, actuators, moving parts.
3. No complex algorithms, no multi-threaded ops
4. Simple hardware/software.
5. As much design work as embedded. 50% engineering, 50% art
6. Doesn't solve a real-world problem.
7. No "stand-out" feature. Everything is just mild.
8. No wireless. no Wi-Fi.

HOW TO MAKE TM8 ᵥₘₒᵣₑ APPEALING TO EMPLOYERS?

1. Implement algorithms
   - → Kalman filter for battery SoC?
   - → Accel readings to crude Gesture control?
     - ↳ low-pass filter, etc.
2. make battery life long AF
   - → this shows knowledge in low-power optimization
3. Think of ways to make TM8 useful IRL
   - → spin off projects?
     - ↳ like openServo in that one guy's MIT maker portfolio
   - → IR receiver can potentially lead to useful real-world apps.
4. Use RTOS if it makes sense to do so
5. Different chipset... with BLE?
   - ↳ Too late... maybe not...?
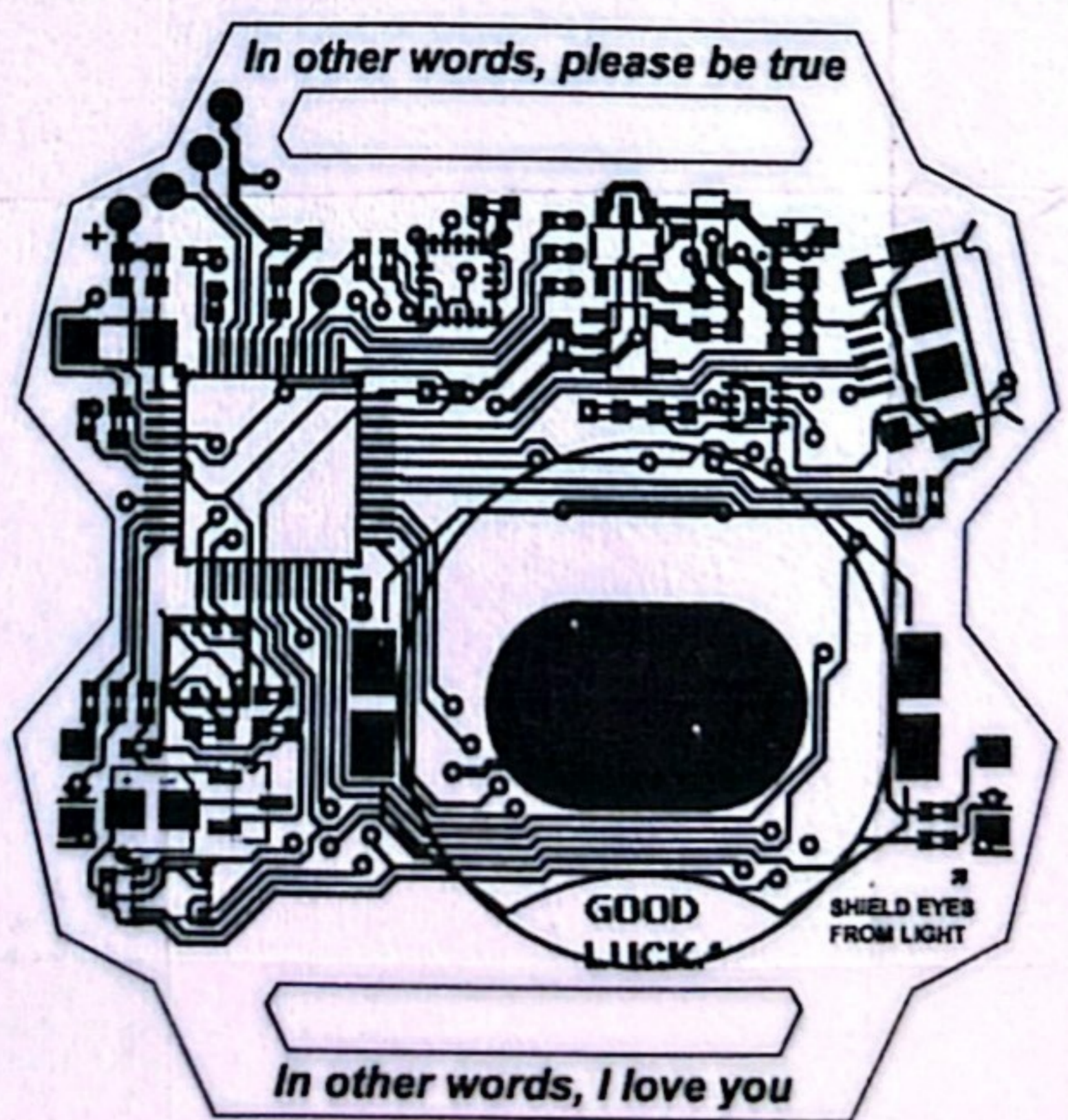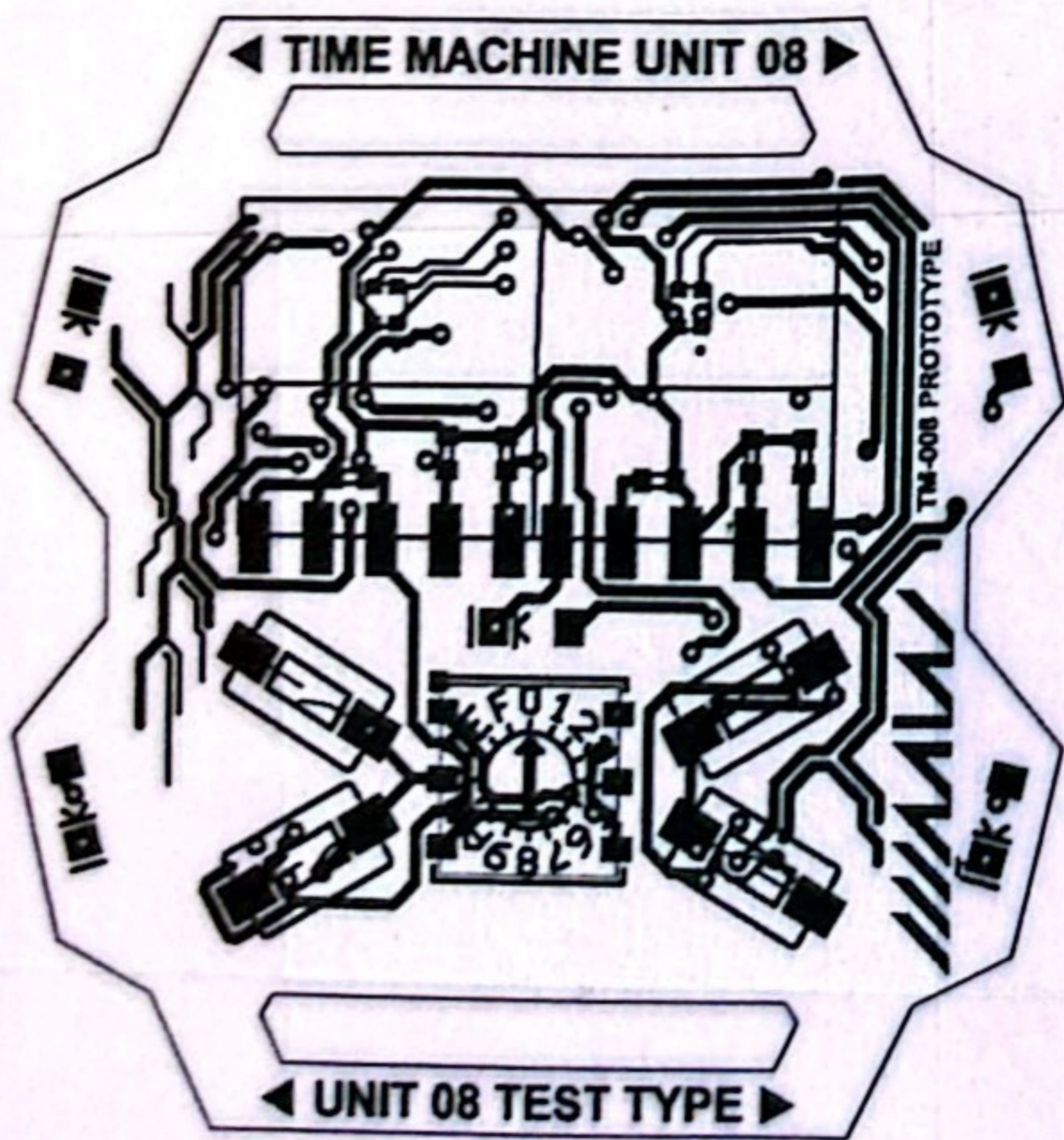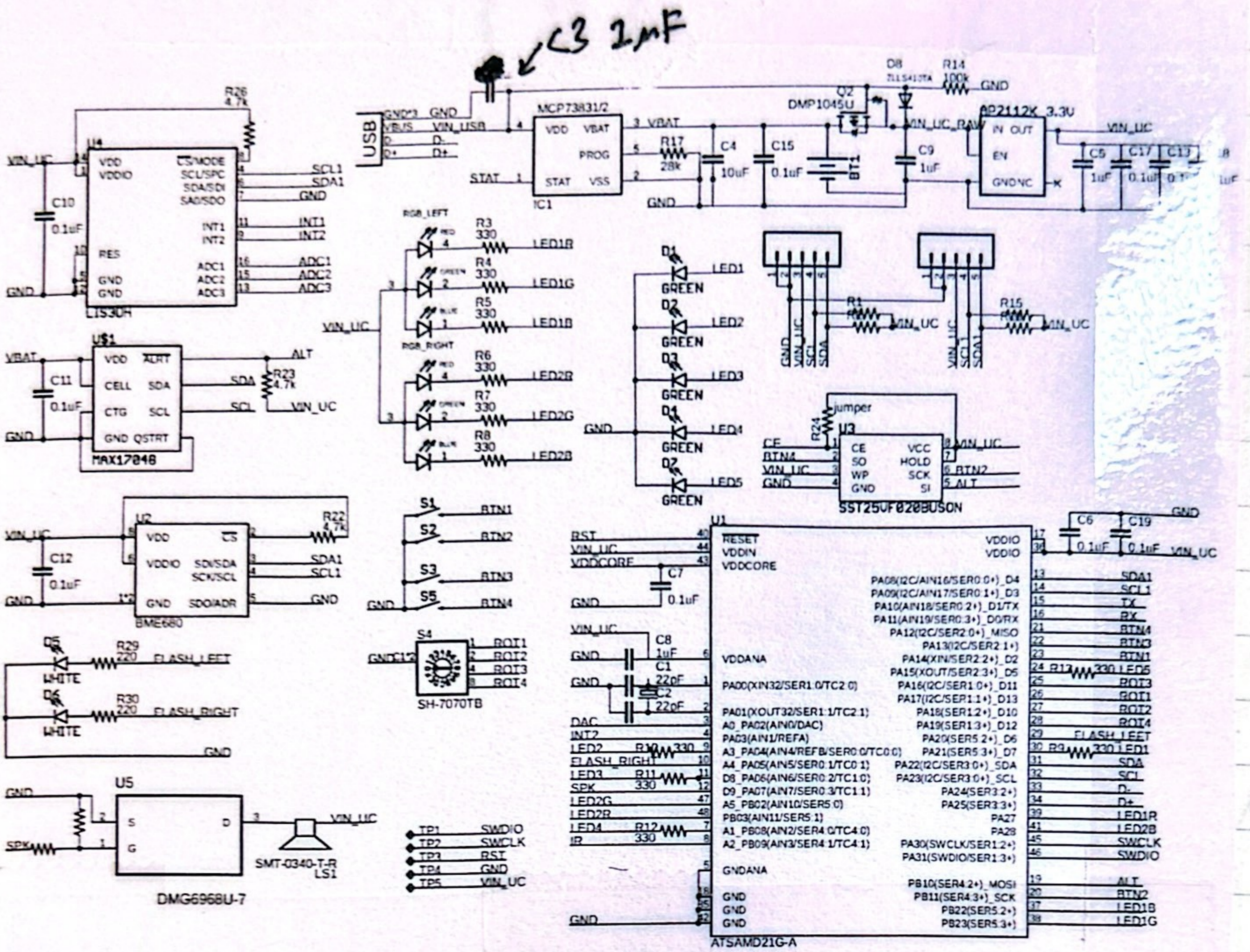   - ↳ ESP-32, NRF52, etc.

STDs:

☒ look into ESP32s and start routing ESP32-based TM8

☑ look into IMUs to replace ~~ADXL~~ LIS3DH

All these crazy MIT maker portfolios have given me insane pasta. Need to step back and take a good look at TM8, re-evaluate the project, and reconsider ~~all~~ all I wrote for the past 2 hours.
   - ↳ BLE/IMU not necessary for TM8, but definitely for TM9.

4/5 updated 1MB.

← C3 2μF

TIME MACHINE UNIT 08 ►

◄ UNIT 08 TEST TYPE ►

In other words, please be true

GOOD LUCK

SHIELD EYES FROM LIGHT

In other words, I love you

TM-008 PROTOTYPE

← TM8 updates:

  ↳ removed all I2C pullups. Only 2 pairs remain under each LCD
       unnecessary

  ↳ N-channel transistor driven buzzer

  ↳ removed IR receiver

  ↳ flipped SPK pins to correct signals.

  ↳ spacing out of parts on back

  ↳ moved USB port closer to edge, now 1.6mm

  ↳ 18mm scrap holes, precise 19.5mm

Other minor updates:

→ moved ~~bypass~~ caps closer to μC, removed ~~excessive~~ unnecessary ones
       decoupling

→ moved PSU closer to edge along with USB port, spread out
   LIS3DH circuitry move.

STDs: 4/6/2023

☑ add test pads for VBAT, ~~VIN~~/ VIN-USB, VIN_USB_RAW

☐ maybe move clock a little inboard

☐ START FINALIZING DESIGN!!!

  ↳ panelize boards. 2 TM8s per PCB?

  ↳ look into each and every signal.

    → check VALUES, PLACEMENT, PINOUTS!

☒ tie all unused I/O to ground!

Custom spec ideas:
Dad's matte black/gold "formal business"
Group C XJR-9 purple/gold "the underdog"
☒ Takumi AE86 white/black/gold "oversteer" "traction loss"

4/10 TM8 ad ideas

"Time flies. Be the pilot."
"Can we get much higher?"
⤷ pic of hand reaching for sky with "so high" on TM8.

"You buy a Rolex when you want to be somebody.
You build a Time machine when you are somebody."

"Some things just work together. Like red solder mask and
electroless nickel immersion gold."

22:06 : added test pads for both I2C buses.
         all test pads 14R size. These will help debug
         I2C related issues.

4/11 TM8 more test pads?

SPI flash pads + extra GND pads?
VBAT pad on right.
D+, D- pads? HOW???
    ⤷ Route across "spit" outside USB port???
DAC test pad?
    ⤷ for clock out for oscilloscope?
    ⤷ or A2 if space doesn't allow?

4/12/2023   Test pads ~~overwork~~ rework

Cleaned up backside and test pads
→ cleaned up and straightened SCL line. Much better now!
→ made perfect triangles for both sensor clusters
  ↳ top: VIN-USB, VIN-UC-RAW, D+
     bottom: SCL, SDA, D−
→ straightened USB test pad lines.
→ added redundant test pads for GND and VIN-UC

23:12: According to Reddit experts at r/embedded, I should
be fine with USB test pads. Speeds not high for messy traces to
be much of an issue.

4/13/2023

STDs:
☒ look into crystal load capacitance and choose
   proper cap values

  ↳ Didn't have time. well, I did, but I watched
     GT4RS POVs instead.

Fixed minor routing niggles. Removed via from BTN4 (MISO)
test pad.

Made triangle bunch test pads below USB port into a slanted "L"
shape for better battery clearance. Also cleaned up ~~battery~~
some traces for better clearance.

According to Reddit experts, stubs on signal lines may introduce
noise to signals. ~~May not be~~

  ↳ play it safe and remove test pads or keep them like a
     boss?

4.14.2023

Nothing.

4.15.2023 PRODUCTION!!!

Put TM8 into production. Fingers crossed!
↳ no errors spotted as of yet (23:53)
Ordering parts on Digi-Key.

4/16/2023 Errors...

Found one (1) fault. BME680 SCL1 pin not
connected. Somehow its traces got ripped up before sending
off for production.
↳ with some careful bodge work this might work out,
but I fully expect the BME680 to not be working.
But good news: no other errors as of yet!

Ordered parts on Digi-Key.

STDs:
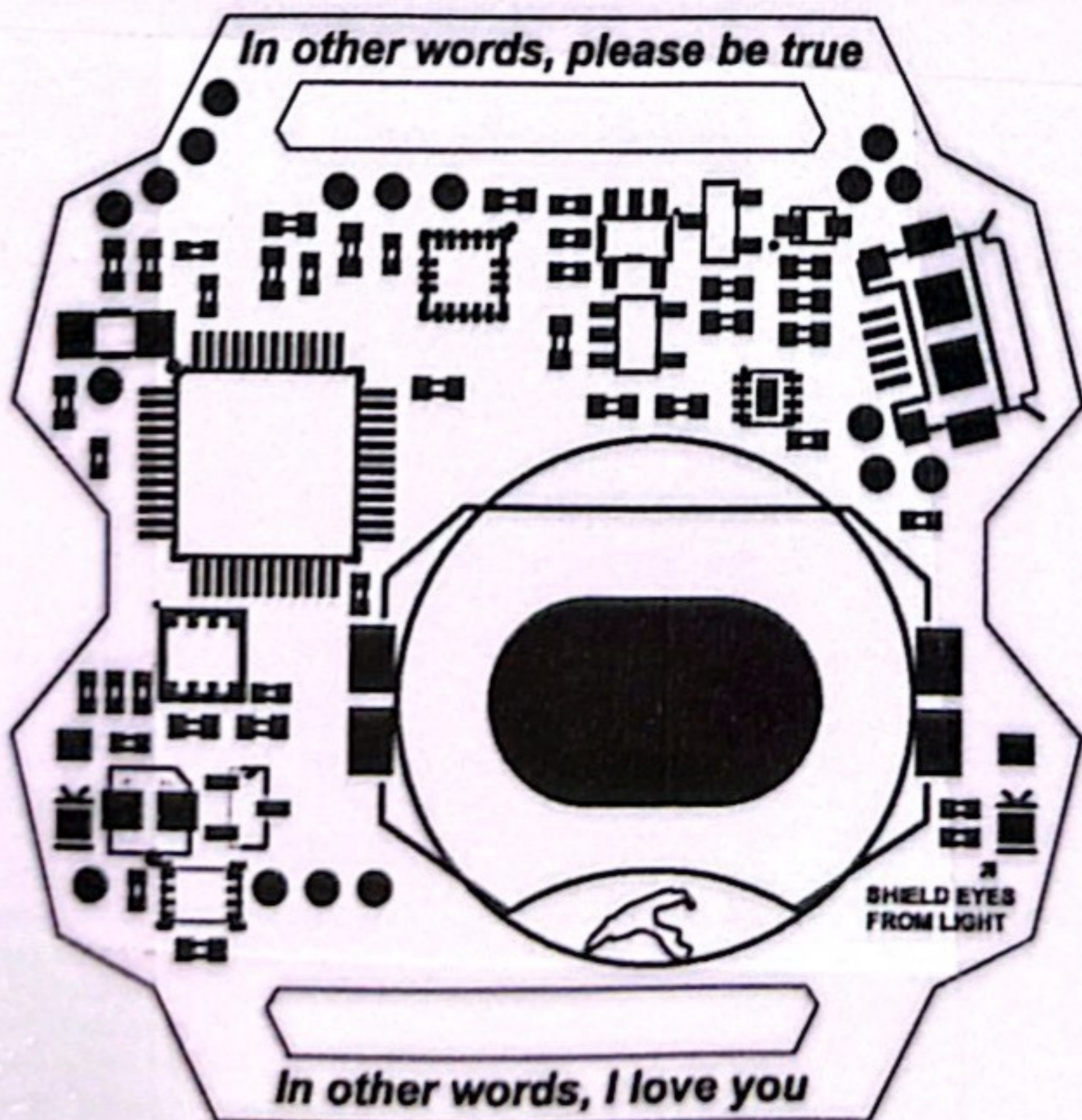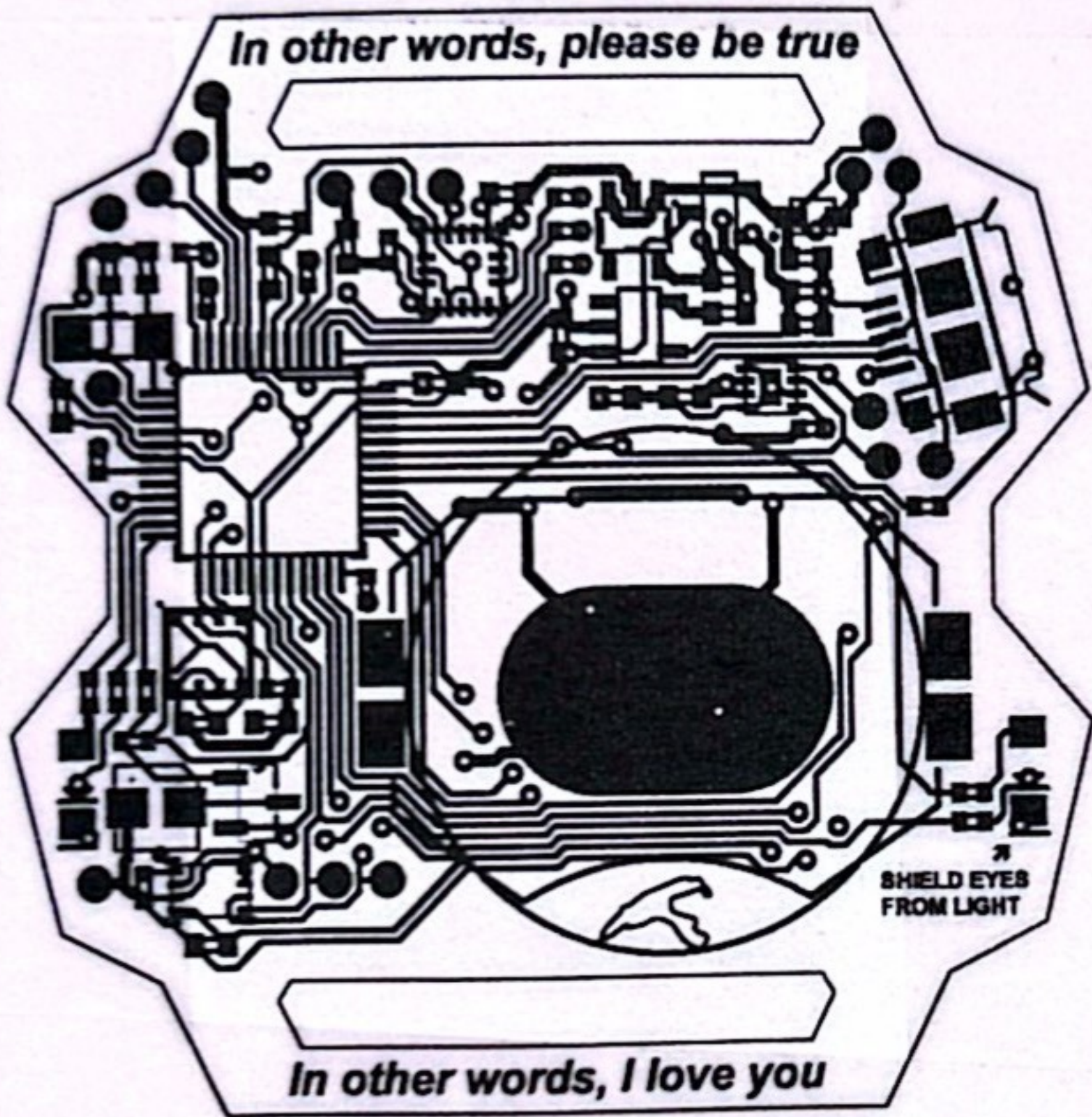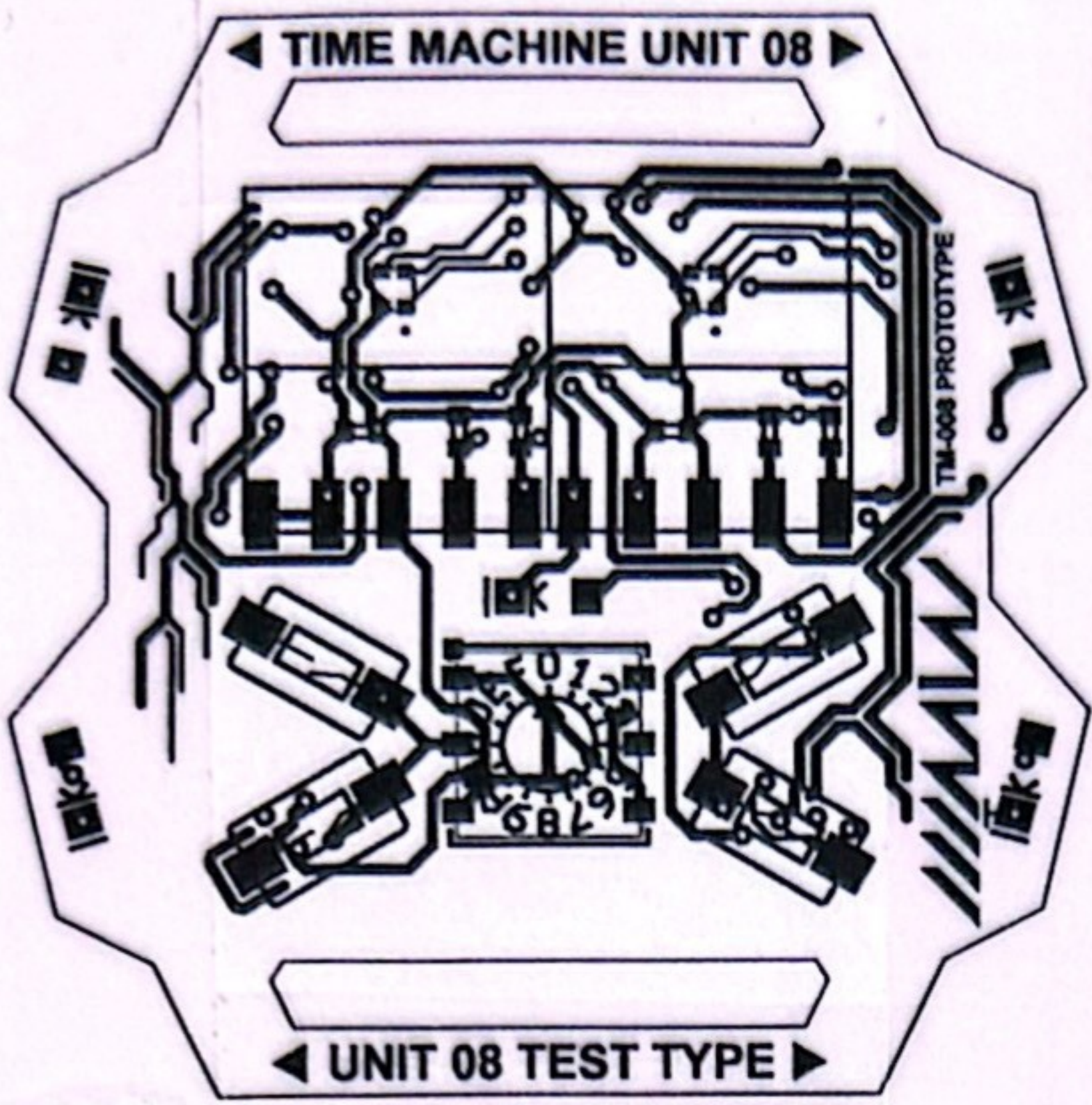↳ clean up schematic and print 50%. ☐
↳ order more parts on Digi-key for propeller project ☑
↳ Root around for more errors ☐

BILL OF MATERIALS:

Item	Qty
ATSAMD21G18A-AU	1
LIS3DH	1
BME680	1
MAX17048	1
MCP73831	1
AP2112K	1
I2C LCD	2
SST25VF020	1
DMP1045U	1
DMG6968U	1
EAST1616RGBA3	2
Green LEDs (1206)	5
White RA LEDs (1206)	2
6.0 x 3.5mm tact switches	4
Micro USB RA	1
Hex rotary switch (7.2mm x 7.2mm SMD)	1
SMT-0340-T-R	1
32.768 KHz crystal (3.2 x 1.5mm 2-SMD no lead)	1
SL03-GS08 Schottky Diode	1
LIR2032 coin cell	1
20mm coin cell holder	1

CAPACITORS: 0.1μF, 1μF, 4.7μF, 10μF, 22pF, (0402)

RESISTORS: 100, 330, 2.2k, 4.7k, 10k, 28k (0402)

TIME MACHINE UNIT 08

UNIT 08 TEST TYPE

TM-008 PROTOTYPE

In other words, please be true

In other words, I love you

SHIELD EYES FROM LIGHT

STDs:
- [ ] Start TM8 on website.
- [ ] Low-power optimizations
- [ ] LCD library make it smoother
- [ ] comment code!

made sick bootup animation.
↳ goes thru I2C bus and checks if all I2C devices are detected.
↳ add LEDs and piezos to it as well!

- [ ] make command input system for watch

5/15/2023
made 3 ads.
↳ R34 GTR brochure inspired one
↳ Two versions of Marble watch Co. one
both look great!

Got very simple 1/1000 second stopwatch working.

STDs

- [ ] make more ads
- [ ] get stopwatch fully working
   ↳ + command input system
   ↳ + optimize for low power

5/16/2023

Can't for the life of me get this thing low-power!

Even with deepSleep() enabled it burns through the battery in like a few hours.
  ⮑ need to find why!, I know lower power is definitely possible.

5/17/2023

Nothing new today. Made some hardware ad tho?
"Can we get much higher?"

STDs
  ☐ low power
  ☑ get LIS3DH and BME680 working
  ☐ incorporate sensors to OS.
    ⮑ menu/command system

5/18/2023

over the weekend...
STDs:
  ☐ call crow
  ☐ make "barebones" firmware

5/18/2023 cont.

Got BIN4 WORKING!!!
↳ thru direct bare-metal port manipulation
↳ probably an issue with board definitions
↳ gotta get all basic I/O to port manipulation now

polishes up menu system. Fully converted. Life's good.

5/22 Implemented chronograph.
  ↳ 5/20 chrono timing accuracy is good!
      only 4/100ths off from P1 official) timing.
      Eyeballed start/finish time for Charles Leclerc's
      monaco pole lap 2022. Very nice. 4/100ths probably
      my own human error

Tried to get chrono to work for the past several
days, no luck. I mean, chrono works, but can't get it
to run in background.

  successfully implemented split recording and playback.

STDs:
☐ implement race chrono
☐ get chrono to run in background
☑ finalize data playback feature
☑ set Time() function
☑ batt. monitor

8/30/2023 wed

UPDATE!!!

TM8 working BEAUTIFULLY!!!

~4 month review

- Still looks beautiful, No real damages at least
  visible to the naked eye.
  ↳ very minor dings and microscratches from
     months of heavy daily use
- Daily brush/clean/wipe makes it look new again.

  Super daily driveable, rarely coddled it. Almost
  daily sweat condensation on back and all good
  after a wipe and boot cycle.

  Not sure if it's sweat or moisture from the
  air, but water condenses onto the back of
  the watch, on the battery holder. Sometimes
  shorts the watch and freezes it. A clean and
  power cycle fixes it.

  Exposed copper: Excellent!
  Silkscreen: Excellent!

  Got new 20mm black NATO strap w/ matte
  black lugs. Looks sexy!

  Overall, ~~often~~ basically no big issues after few
  months of daily usage !!!
       heavy