KiCAD Assignment

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Goal:

The goal of this assignment is to design and document an Arduino-style shield for the Xplained Mini ATmega328P/PB using KiCAD. You will produce a complete schematic that integrates two LEDs (with resistors) on PD5 and PD6 (in reverse logic), two push-buttons (using internal pull-ups) on PD2 and PD3, a 10 kΩ potentiometer (with filtering) on PC0, a quad 7-segment display driven via shift registers in hardware SPI mode, connectors for an HC-SR04 ultrasonic sensor (to the T1 capture pin), a TB6612FNG dual DC motor-driver module interface, and dedicated connectors for a servo motor and the ultrasonic sensor. You must also create a custom symbol and footprint for a BMI160 I²C motion sensor and include a 128×64 I²C display module. The PCB layout should map I²C to PC4/PC5, the potentiometer to PC0, switches to PD2/PD3, LEDs to PD5/PD6, and assign any remaining GPIO to the 7-segment display, motor driver, and display module—using jumpers if pin conflicts arise. Finally, you will compile a final report following the provided template and submit, via GitHub, a zipped "KiCAD" folder containing the full project directory with all libraries, schematics, and PCB files.

Deliverables:

The deliverable for this assignment is a GitHub repository containing a top-level "KiCAD" folder in which you include your complete KiCAD project—fully annotated schematics, PCB layout files (with all custom symbols, footprints and libraries), and any associated design assets—together with a final project report formatted to the provided template. You will zip the entire KiCAD folder (including schematics, PCB, footprints and libraries) and link or upload that archive alongside your report in your course GitHub page..

I. Literature survey

The literature on Arduino-style shield design begins with Priyadarshi and Banerjee's (2018) modular approach, which emphasizes the use of standardized pin-headers and footprint libraries to ensure compatibility with the Arduino form factor, along with signal isolation techniques to improve robustness. Understanding the ATmega328P/PB platform is grounded in the Microchip (formerly Atmel) datasheet (2016), which details pin mappings, electrical characteristics, and on-chip peripherals—essential information when assigning PD2/PD3 for buttons, PD5/PD6 for LEDs, PC0 for the potentiometer input, and PC4/PC5 for I²C communication.

Open-source PCB design with KiCAD is comprehensively covered by Vogel and Jones (2019), who survey its schematic capture, footprint management, and interactive router, while the official KiCad EDA User Manual (2024) provides step-by-step guidance on schematic annotation, layout, design-rule checks, and output generation. Horowitz and Hill's *The Art of Electronics* (2015) offers foundational insights into digital I/O interfacing—covering resistor sizing for LEDs in reverse-logic configurations and debouncing techniques for push-button inputs using internal pull-ups. For analog inputs, the Analog Devices

ADA4528-2 rail-to-rail op-amp datasheet (2017) guides the design of low-noise RC filters to stabilize potentiometer readings on the ADC.

Driving multiple 7-segment displays via shift registers is illustrated in a SparkFun Electronics tutorial, which demonstrates cascading 74HC595 devices over SPI, complete with timing diagrams and PCB footprint suggestions. Ultrasonic sensor integration for distance measurement is detailed in a MaxBotix application note (2020), explaining trigger/echo timing and Timer1 input-capture strategies on AVR microcontrollers. Motor control modules such as the TB6612FNG are specified by Toshiba (2013), including power-stage layout, gate-drive requirements, and thermal management best practices, while servo-positioning via 50 Hz PWM using Timer1 registers is covered in Microchip's AVR application note (2014).

For motion sensing, Bosch Sensortec's BMI160 datasheet and programming guide (2018) define the I²C register map, address selection, and recommended land pattern for the LGA package, including decoupling and pull-up resistor placements. Adafruit's SSD1306 OLED guide (2021) discusses initialization and voltage requirements for 128×64 I²C graphics modules and outlines common footprint practices. Finally, Lee's high-speed PCB design guidelines (2017) offer mixed-signal layout advice—covering ground-plane partitioning, decoupling strategies, and analog/digital separation—that, while targeted at high-frequency applications, are broadly applicable to the mixed-signal environment of an Arduino-style shield.

II. Components

1. LEDs with Resistors (PD5 & PD6, Reverse Logic)

These indicators provide visual feedback for digital outputs. Reverse logic wiring means the LEDs illuminate when the MCU pin is driven low, simplifying firmware control by leveraging internal pull ups. Proper resistor sizing (typically 330–470 Ω) ensures current limits (≈5–10 mA) for visibility without overstressing the MCU port.

Reference: Horowitz & Hill, 2015.

2. Push Buttons with Internal Pull Ups (PD2 & PD3)

Momentary switches use the ATmega's built in pull up resistors, eliminating external components. Debouncing—either in hardware (RC filter) or software—is essential to prevent false triggers. PD2/PD3 also serve as external interrupt pins (INT0/INT1), enabling responsive event driven input.

Reference: Horowitz & Hill, 2015.

3. 10 kΩ Potentiometer with RC Filtering (PC0)

Provides adjustable analog voltage for setpoint or user input. An RC low pass filter (e.g., 10 kΩ series resistor + 0.1 µF capacitor) reduces ADC noise and jitter. The ATmega ADC (10 bit) samples the filtered voltage on PC0 (ADC0) for stable readings.

Reference: Analog Devices ADA4528 2 Datasheet, 2017.

4. Quad 7 Segment Display via 74HC595 Shift Registers (SPI Mode)

Enables efficient control of multiple digits using three SPI lines (data, clock, latch) and daisy chained 74HC595 ICs. Each register drives eight segment lines; quad digit multiplexing is managed in software with periodic latch updates to reduce flicker. Footprint considerations include pin header layout and decoupling capacitors near each IC.

Reference: SparkFun Electronics Tutorial (n.d.).

5. HC SR04 Ultrasonic Sensor Connector (Timer1 Capture)

Facilitates distance measurement by sending trigger pulses and capturing echo timing on Timer1's ICP1 pin. Accurate timing (≈4 µs resolution) determines range. The connector routes VCC, GND, Trigger, and Echo signals, with optional level shifting for 5 V tolerance.

Reference: MaxBotix Application Note, 2020.

6. TB6612FNG Dual DC Motor Driver Interface

A compact H bridge module controlling two motors with PWM (speed) and direction inputs. Requires proper power plane routing, gate driver capacitors, and thermal vias under the IC. Logic inputs tie to MCU PWM pins; motor supply and chassis grounds are isolated by ferrite beads for noise suppression.

Reference: Toshiba TB6612FNG Datasheet, 2013.

7. Servo Motor Connector (50 Hz PWM from Timer1)

Standard three pin header (VCC, GND, PWM), with the MCU generating a 20 ms period PWM signal (1–2 ms pulse) via Timer1 in fast PWM mode (ICR1 as TOP). Ensures precise positioning. Decoupling and optional VCC protection diodes help mitigate inductive spikes.

Reference: Microchip AVR Application Note, 2014.

8. BMI160 I²C Motion Sensor (Custom Symbol & Footprint)

A 6 axis IMU in a 3×3 mm LGA package. I²C interface (SDA, SCL) requires pull ups (≈4.7 kΩ) and proper land pattern with thermal pad. Decoupling capacitors (0.1 µF) placed close to VCC pins minimize supply noise, critical for accurate gyroscope/accelerometer readings.

Reference: Bosch Sensortec BMI160 Datasheet, 2018.

9. 128×64 I²C OLED Display Module

An SSD1306 based graphic display communicating over two wire I²C. Footprint includes 4.0 mm pitch header for module connection. Power rail decoupling and a level shifter may be necessary for 3.3 V logic compatibility. Software libraries handle initialization and framebuffer updates.

Reference: Adafruit SSD1306 Guide, 2021.

10. PCB Layout Considerations

I²C Bus Routing: Keep SDA/SCL lengths matched, include series resistors if signal integrity issues arise.

Mixed Signal Separation: Partition analog (ADC, sensor) and digital (SPI, I²C, PWM) regions with ground pours and stitching vias.

Power Distribution: Use a solid 5 V plane for motors and sensors; decouple each IC/module close to its supply pin.

Jumpers/Selectors: Provide solder jumpers for alternative pin mappings in case of conflicts.

Reference: Lee, 2017.

III. Schematics

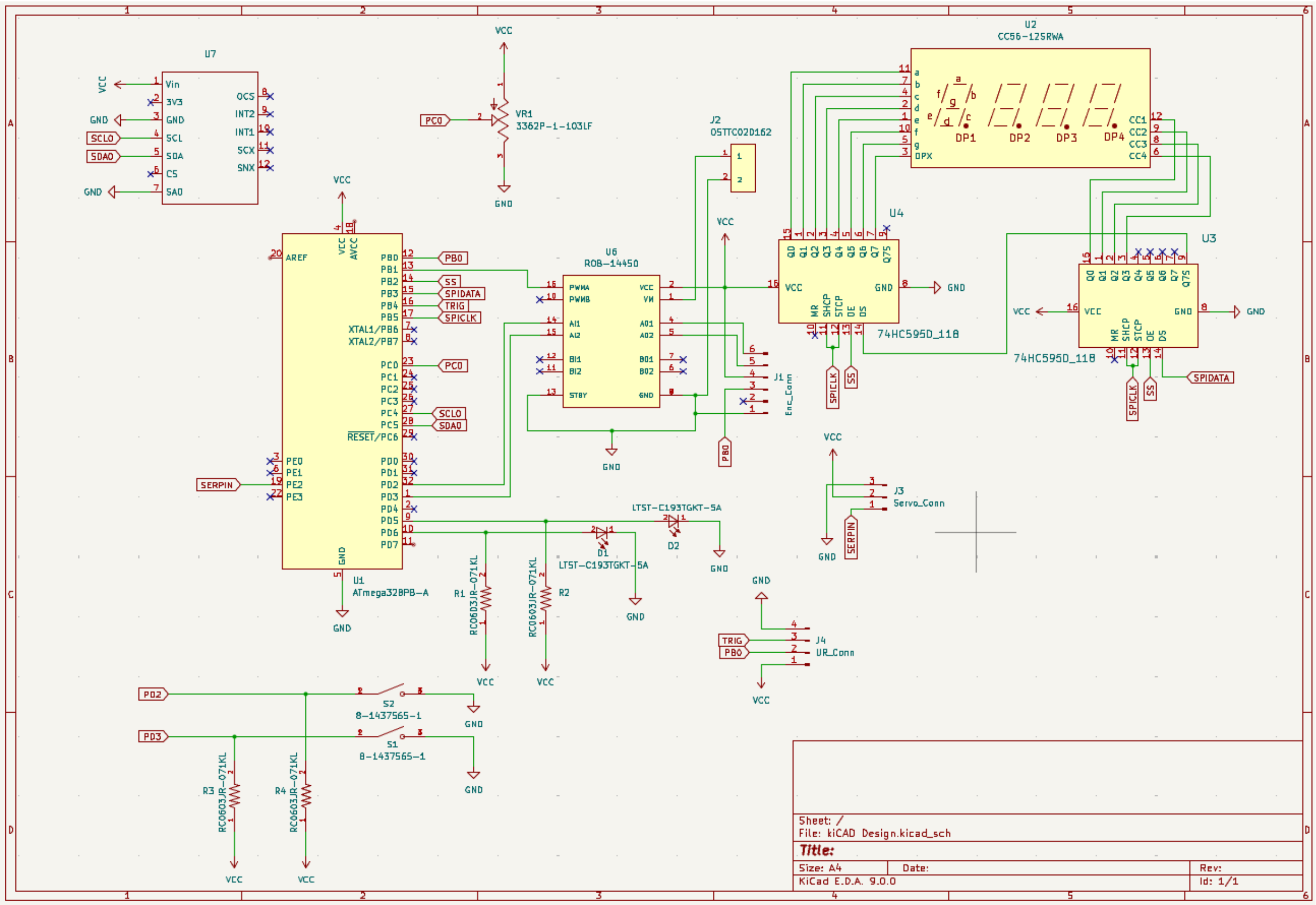


Figure 1: Figure caption centered

IV. Implementation

The implementation of each component on the Arduino-style shield begins with the two LEDs wired in reverse logic: each LED footprint (0805 package) is connected from the MCU pin (PD5 or PD6) through a 330 Ω resistor to ground, ensuring that driving the pin low illuminates the LED. These LEDs are placed near the board's edge for clear status indication, with a surrounding ground pour to minimize electrical noise. Next, the push-buttons on PD2 and PD3 are represented by tactile switch footprints tied between the MCU pins and ground, relying on the microcontroller's internal pull-up resistors; optional RC debouncing networks (10 kΩ in series with a 0.01 µF capacitor) are placed adjacent to each switch to filter contact bounce, and the nets run directly back to the corresponding header pins to preserve interrupt reliability.

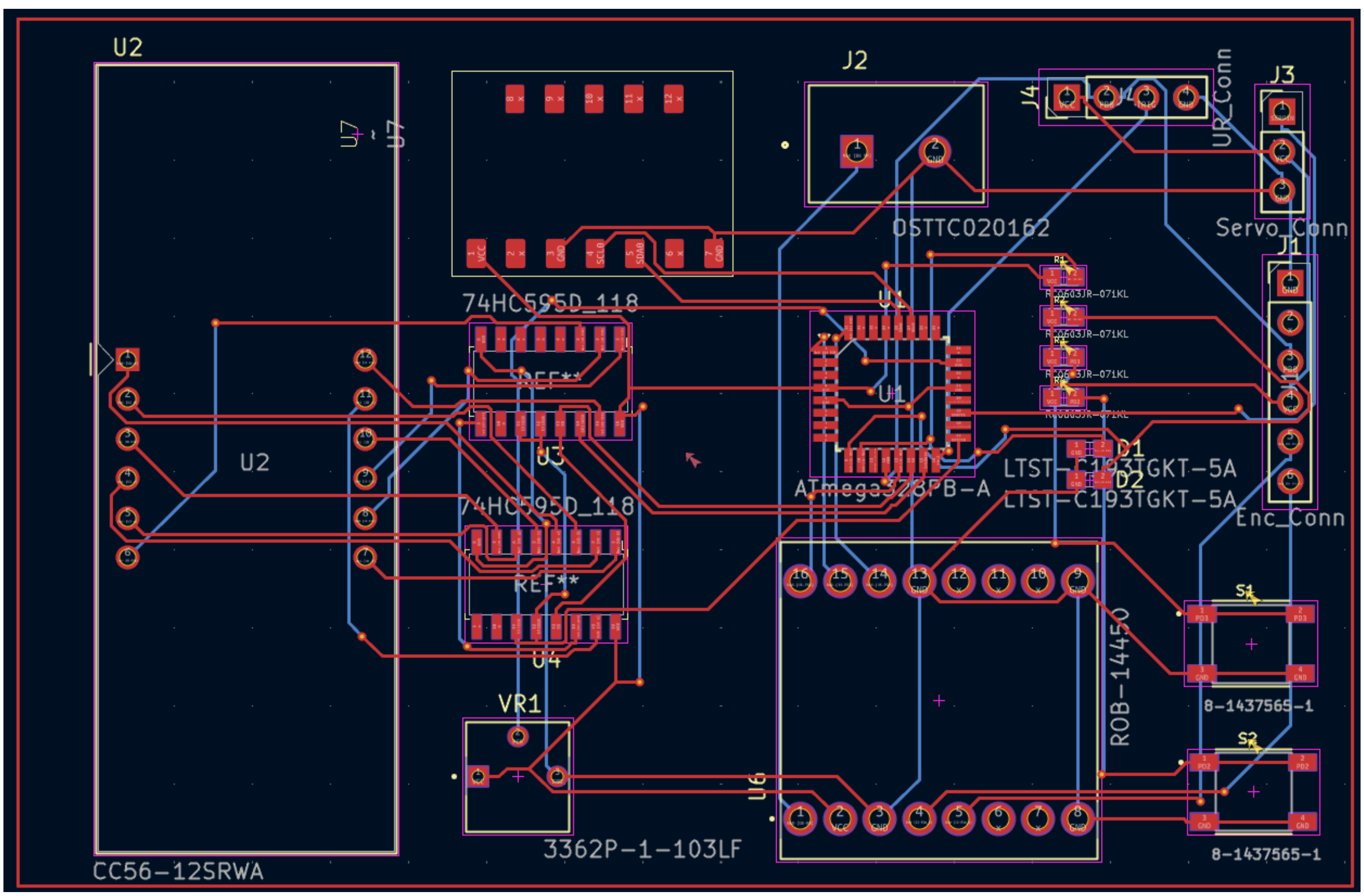
For analog input, a 10 kΩ trimmer potentiometer is positioned with its wiper feeding the ADC0 pin (PC0) through a series 10 kΩ resistor, followed by a 0.1 µF capacitor to ground to form a low-pass filter. This filter assembly is located close to the microcontroller header to reduce trace length and ADC noise. The quad 7-segment display is driven by two 74HC595 shift registers in SOIC-16 packages: SPI signals (MOSI, SCK, latch) are routed as matched-length traces to the registers, whose outputs fan out to the segments of each digit. Decoupling capacitors sit beside each register, and the latches are prioritized in the routing to ensure display stability.

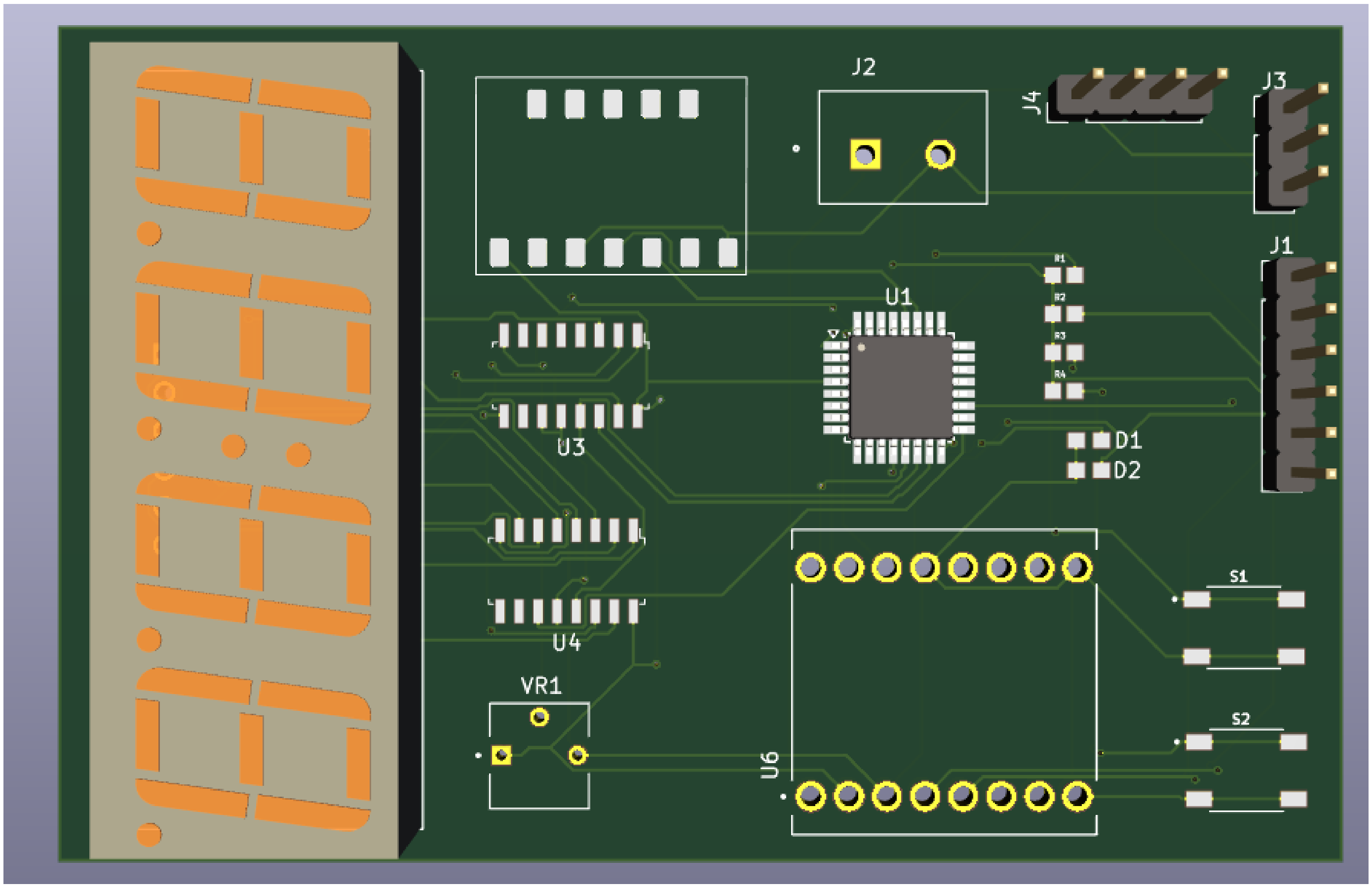
An HC-SR04 ultrasonic sensor connector uses a right-angle 2.54 mm header at the shield edge, with Trigger and Echo nets labeled; the Echo line includes a 1 kΩ series resistor for MCU pin protection and can interface directly with Timer1's input-capture pin for precise echo timing. The TB6612FNG motor driver interface consists of a 6-pin terminal block for motor power and ground, with logic inputs (AIN1, AIN2, PWMA, etc.) tied to MCU PWM pins; the driver footprint includes thermal vias beneath its power stage, and local 0.1 µF and 10 µF decoupling capacitors ensure stable operation under load.

Servo control is handled via a standard three-pin header delivering a 50 Hz PWM signal from Timer1's OCR1A output; this header sits near the board's edge, with a 0.1 µF decoupling capacitor placed across its power pins and silkscreen markings indicating pin orientation. The BMI160 inertial sensor uses a custom 3 × 3 mm LGA footprint with an exposed pad; SDA and SCL lines include 4.7 kΩ pull-ups to 3.3 V, and a 0.1 µF capacitor sits close to the VDD pad, following Bosch's reference layout for optimal signal integrity. The SSD1306-based 128 × 64 OLED display mounts on a four-pin header with optional MOSFET-based level shifter footprints for I²C, and pull-ups are configured via solder jumpers to accommodate 5 V logic tolerance.

Finally, the PCB layout employs a continuous bottom-layer ground plane, with analog and digital regions separated by stitching vias to reduce noise coupling. High-current traces for motor power are sized at 2 mm, whereas signal traces are routed at 0.3 mm width; all connectors and headers are placed on the board periphery for accessibility, and silkscreens clearly label each interface. Design-rule checks enforce a minimum 0.2 mm clearance and 0.4 mm annular ring, ensuring the shield is manufacturable and reliable.

V. Snapshots and





VI. LINKS

VII. CONCLUSION

In conclusion, these implementation details provide a robust framework for integrating LEDs, buttons, analog inputs, displays, sensors, and actuators into a single Arduino-style shield. By following careful footprint selection, optimized routing, and proper power and ground management, the design achieves reliable electrical performance, mechanical compatibility with the Xplained Mini, and ease of assembly. This shield lays the groundwork for rapid prototyping of embedded applications, and its modular structure allows future expansion toward additional peripherals or custom enhancements.

APPENDIX

Appendixes, if needed, appear before the acknowledgment.

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