Smart Ultrasonic Humidifier: Design Report

G. Vamshi Krishna

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1 Introduction

This report presents the design of a smart ultrasonic humidifier system, controlled via a push button and an HC-05 Bluetooth module for wireless operation. Built around the ATmega328P microcontroller, the system integrates a Techtonics 5V ultrasonic humidifier module, an IRFZ44N MOSFET, a status LED, and supporting components. The design prioritizes reliability, simplicity, and production readiness, featuring a compact 80mm x 60mm PCB layout optimized for manufacturability. This report covers component selection rationale, control logic, production optimizations, and solutions to design challenges.

2 Component Selection Rationale

The system's components were selected for performance, cost-effectiveness, and production compatibility:

- ATmega328P Microcontroller (DIP-28): Chosen for its 23 I/O pins and 32KB flash memory, sufficient for button input, Bluetooth interfacing, and output control. Its 5V operation matches the humidifier module, simplifying power management. The DIP-28 package supports prototyping and repair, while its low cost ensures scalability.
- HC-05 Bluetooth Module: Enables wireless control via a smartphone, offering reliable communication. Its low cost and compatibility with the ATmega328P make it ideal for remote operation.
- Techtonics 5V Ultrasonic Humidifier Module: A compact, USB-powered module with an atomizing chip, requiring minimal external components. Its 5V operation aligns with the system's power supply.
- IRFZ44N MOSFET: An N-channel MOSFET with low Rds(on) (17.5mΩ) and high current capacity (49A), ideal for switching the humidifier's power. Its 5V gate drive compatibility allows direct control from the ATmega328P.
- Push Button: A momentary tactile switch with a 10kΩ pull-up resistor on PD2 (INT0) for manual control. Its simplicity ensures reliability.
- Status LED: A 5mm LED with a 330Ω resistor provides visual feedback of the humidifier's state.
- Passive Components: Two 0.1μF decoupling capacitors stabilize the power supply, 22pF capacitors support the 16 MHz crystal for accurate timing, and a 220Ω gate resistor protects the MOSFET. Standard values ensure availability.
- ISP Header: A 6-pin header for in-circuit programming, using standard 2.54mm spacing for compatibility with programmers.

3 Control Logic

The ATmega328P processes push-button and Bluetooth inputs to control the humidifier via the IRFZ44N MOSFET, with a status LED indicating the system state:

- Push Button (PD2, INT0): Connected to an external interrupt pin with a pull-up resistor. A button press triggers a software-debounced toggle function, switching the humidifier state (ON/OFF). The state is stored in a global variable and reflected on the MOSFET and LED.
- HC-05 Bluetooth Module: Facilitates wireless control through a smartphone, allowing ON/OFF commands to toggle the humidifier state, which is updated on the MOSFET and LED.
- MOSFET (PD3): Outputs a HIGH/LOW signal via a 220Ω resistor to the IRFZ44N gate, controlling power to the humidifier module. The MOSFET's source connects to GND, and its drain connects to the humidifier's GND side, with the humidifier's +V tied to the 5V supply.
- Status LED (PD4): Driven HIGH/LOW via a 330Ω resistor to indicate the humidifier's state (ON = lit, OFF = unlit).

The control logic uses an interrupt-driven approach for the push button, with a 20ms software debounce delay to mitigate noise. Bluetooth commands are processed to ensure seamless wireless operation, synchronizing the humidifier and LED states.

4 Production Optimizations

The PCB design and component choices were optimized for manufacturability and reliability:

- PCB Layout: The 80mm x 60mm rectangular board uses a poured GND plane (bottom layer) to reduce noise and improve power distribution. Components are placed to minimize trace crossovers, with high-current paths (MOSFET to humidifier) using wider traces (1mm) to reduce resistance. Net clearances of 0.2mm meet standard manufacturing tolerances.
- Component Selection: Through-hole components (e.g., DIP-28 ATmega328P, 2.54mm headers) simplify hand soldering and repair, ideal for prototyping and small-scale production. Standard passive components (e.g., 0.1μF capacitors, 220Ω resistors) reduce costs.
- Design for Manufacturability: The layout avoids acute angles in traces, uses standard 2.54mm headers, and ensures 0.8mm minimum spacing for automated assembly. The ISP header supports in-circuit programming, streamlining production.
- Power Management: The 5V adapter connects via a 2-pin header, with decoupling capacitors near the ATmega328P and HC-05 to filter noise. The IRFZ44N's low Rds(on) minimizes heat, eliminating the need for a heat sink.

5 Challenges and Solutions

- Bluetooth Interference: The HC-05 may face signal noise in crowded environments. Solution: Configured the HC-05 with a unique device name to reduce interference.
- Power Consumption: The humidifier module draws significant current (up to 1A). Solution: The IRFZ44N's high current capacity and low Rds(on) ensure efficient switching, with a 5V regulator stabilizing the supply.
- Button Noise: Mechanical switches can produce bounce. Solution: A 20ms software debounce delay ensures reliable input detection.

6 Conclusion

The smart ultrasonic humidifier system leverages the ATmega328P's I/O capabilities to deliver reliable push-button and Bluetooth-based control. The IRFZ44N MOSFET enables efficient power switching, while the optimized PCB layout and standard components enhance production readiness. Challenges like interference, power consumption, and button noise were addressed through careful design and software solutions. This design balances performance, cost, and manufacturability, making it suitable for production and adaptable for future enhancements, such as adding a humidity sensor.