

Design and Installation of a Low-Cost Solar-Powered IoT Device for Ammonia Monitoring in Small Home Chicken Coops

Muhammad Bentang Subing Mandiri Masputera¹, Masnon Rizkina Puteri²

¹SMAS YP UNILA Bandar Lampung, Indonesia · ²SMAN 9 Bandar Lampung, Indonesia

Abstract

Ammonia from chicken manure is a common problem in small home poultry coops in crowded city areas, yet ready-made NH₃ monitors cost IDR 1.5–5 million, far too much for a farmer who keeps five to ten hens. This paper describes how we designed, built and installed a monitoring device made from common parts for IDR 189,100 (about USD 12). The device uses an MQ-135 gas sensor, a DHT22 temperature and humidity sensor, a small LCD screen, an indicator LED and a buzzer, all controlled by a NodeMCU ESP8266. Power comes from a 2600 mAh Li-ion battery charged by a 5 V, 1 W solar panel. Two design choices make it different from earlier low-cost monitors. First, the MQ-135 heater is turned on and off by a P-channel MOSFET, so it can be switched off between readings to save power. Second, the ppm value is corrected using the temperature measured at the same moment, not a fixed value. Our calculation shows the device uses about 1,018 mAh per day, which means it can run for 61 hours with no sunlight. The device has been installed on a working coop with five laying hens in a crowded neighbourhood in Bandar Lampung. Testing the sensor against certified reference gas and running it for a long period are not covered here and remain to be done.

Keywords: ammonia, MQ-135, ESP8266, solar power, chicken coop, low-cost sensor

1. Introduction

Keeping a few laying hens behind the house is common in Indonesian cities where land is limited. The coops stand only a few metres from where people live, and the ammonia gas made by bacteria breaking down the manure spreads easily into nearby houses. Levels above 25 ppm can irritate the eyes and airways and lower egg production [1], [2]. In small Indonesian coops the reported levels vary widely, from 0.36 to 197.56 ppm, depending on air flow and when the reading is taken [3].

Two problems stop farmers from monitoring the gas all the time. The first is that they rely on smell, which fails exactly when it matters most: a farmer who enters the coop every day stops noticing the smell, and the highest levels build up before sunrise when nobody is there [4]. The second is price. Ready-made NH₃ meters start at IDR 1.5 million, which equals several months of egg income for a flock this size.

Earlier low-cost monitors solve part of the problem. Supriyono et al. [3] built a temperature and ammonia monitor for small coops that sends alerts through Telegram, and Arifin et al. [5] sent MQ-135 readings to ThingSpeak using an ESP8266. Both need a permanent mains cable running into a wet, dusty place, and neither corrects the gas reading for the temperature at the time of measurement. This paper describes a device built to address these two gaps, and how it was installed on a working coop.

2. Hardware

The device is built around a NodeMCU ESP8266, as shown in Fig. 1. A 5 V, 1 W solar panel charges a 2600 mAh 18650 battery through a battery shield, which also raises the battery voltage to 5 V. This 5 V enters the board through the micro-USB port and is then shared from the VIN pin to the other 5 V parts. The DHT22 takes its power from the 3.3 V pin of the board.

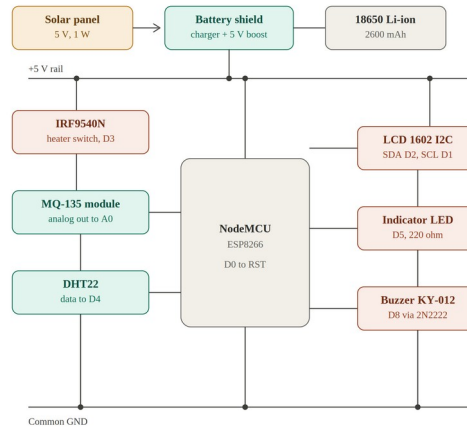


Fig. 1. Block diagram of the solar-powered ammonia monitoring device.

The MQ-135 output does not go straight to pin A0. The sensor runs on 5 V, so its output can reach 5 V, which is above the 3.3 V limit of the analog input. A voltage divider made of 4.7 k Ω and 9.4 k Ω resistors turns the 0–5 V range into 0–3.333 V. This keeps the input safe and still uses the full range of the converter.

The heater inside the MQ-135 has a 33 Ω element running on 5 V and draws about 150 mA all the time. This is the largest power user in the whole device. To allow it to be switched off between readings, the sensor module is powered through an IRF9540N P-channel MOSFET placed on the positive side. The switch must be on the positive side, not the simpler ground side, because the sensor shares its ground with the analog signal; cutting the ground would leave the reading without a stable reference. The GPIO pin can only reach 3.3 V while the MOSFET source sits at 5 V, so a 2N2222 transistor is used to drive the gate, with a 9.4 k Ω pull-up resistor keeping the MOSFET off by default.

The warning part uses two different methods. One indicator LED on pin D5 with a 220 Ω resistor draws 5.9 mA, well below the 12 mA limit of a single pin. Instead of using several lamps, the level of danger is shown by how the LED blinks: off when safe, steady at 15–20 ppm, slow blinking at 20–25 ppm, and fast blinking above 25 ppm. The KY-012 buzzer needs more current than a pin can give, so it is switched by a second 2N2222 on the ground side. An LCD 1602 with an I2C module shows the reading at the coop without needing a phone.

Table 1 lists the parts and their prices. The total of IDR 189,100 is about 87 % cheaper than the lowest-priced ready-made NH₃ monitor sold locally.

Table 1. Parts and prices.

Component	Specification	Cost (IDR)
NodeMCU ESP8266	V3, CH340, 3.3/5 V	35,000
MQ-135 module	analog output, 5 V supply	18,000
DHT22	digital, ± 2 $^{\circ}\text{C}$, ± 5 %RH	15,000
LCD 1602 + I2C	16 $\times$ 2 characters, addr. 0x27	28,000
Solar panel	5 V, 1 W, I_{max} 200 mA	33,000
Battery shield	micro-USB in, 5 V out	20,000
18650 cell	Li-ion 3.7 V, 2600 mAh	20,000
IRF9540N	P-channel switch, positive side	3,000
2 $\times$ 2N2222	buzzer driver + gate driver	15,000
Resistors, LED	divider, 220 Ω , pull-up, 5 mm LED	2,100
Total		189,100

3. Program and measurement cycle

The program is written in C++ using the Arduino IDE. Between readings the ESP8266 goes into deep sleep and the heater is switched off. Pin D0 is connected to RST so the board can wake itself up, which is why the buzzer uses pin D8 instead. The WiFi settings use a fixed IP address, so connecting takes one to two seconds instead of five to eight. This keeps the awake time short.

One cycle runs every 30 minutes and follows these steps: turn on the heater, wait 90 s for the sensor to warm up, take the average of ten readings, convert them to resistance and then to ppm using the datasheet curve, read the DHT22, apply the temperature correction, update the screen and the indicators, and send the data to ThingSpeak. Between 04:00 and 07:00, when the gas builds up most, the cycle shortens to 10 minutes. The clock time comes from an NTP server because `millis()` goes back to zero every time the board wakes up. Above 25 ppm the device does not sleep at all. It stays awake and reads every minute, so the LED and buzzer keep working while the problem lasts.

The temperature correction follows the datasheet method of Fosalau et al. [6], written as $\text{ppm_corrected} = \text{ppm_raw} / (1 + \alpha (T - T_{\text{ref}}))$, with $T_{\text{ref}} = 25\text{ }^{\circ}\text{C}$. What makes it different here is that T is the value read by the DHT22 in the same cycle, not a fixed number chosen beforehand. The correction therefore follows the daily temperature change inside the coop.

4. Power use

The figures below are calculated from datasheet values and typical currents. They have not yet been checked with a meter. With the heater switched on for about 7 % of the time and the screen backlight turned on above the caution level, the device draws about 42 mAh per hour, or 1,018 mAh per day. That is 39 % of the battery. A full battery should therefore run the device for about 61 hours with no sunlight at all.

The 1 W panel gives at most 200 mA in full sunlight, so a clear day produces around 1,000 mAh and roughly matches what the device uses. On cloudy days the panel gives less and the battery makes up the difference. For this reason we call the design a solar-battery hybrid rather than off-grid: the panel makes charging less frequent, but does not remove it. Matching supply and demand in all weather would need a panel of about 5–10 W. We note this as future work and do not claim it here.

5. Building and installing the device

The circuit was built on a protoboard inside an IP54 plastic box (Fig. 2). The MQ-135 and the DHT22 are placed near the vented side of the box so air can reach them, while the battery, the shield and the microcontroller sit behind.

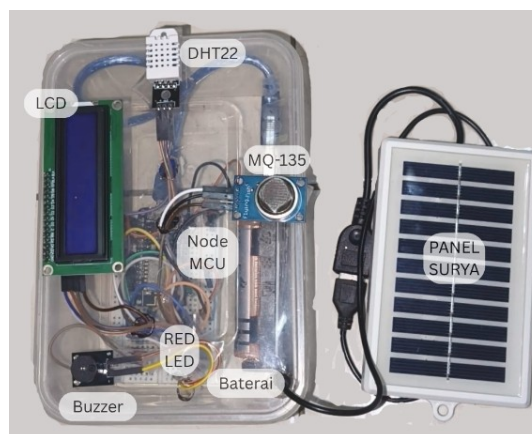


Fig. 2. The finished device in its IP54 box, with the 5 V solar panel.

The device was installed on a working coop with five laying hens in a crowded neighbourhood in Bandar Lampung (Fig. 3). The box is tied to the cage frame at the same height as the birds, where the gas that affects them collects, and the panel is tied to the top of the cage facing open sky. No mains cable enters the coop. This was the main practical goal, because a wet, dusty place full of ammonia is where fixed wiring breaks down fastest.



Fig. 3. The device installed on a working chicken coop in a crowded neighbourhood.

Installing the device needs nothing more than cable ties. During setup the LCD screen turned out to be the most useful part, because it shows the current reading without opening an app or depending on the home WiFi.

6. Limitations

This report covers the design and the installation. Three things are not claimed here. First, the sensor has not been tested against certified reference gas, so the ppm values should be treated as a guide rather than exact numbers. The baseline resistance R_0 also has to be measured again under the on-and-off heating used here, because it is different from the always-on heating assumed in the datasheet. Second, the power figures are calculated, not measured. Third, the MQ-135 also reacts to CO₂, alcohol and benzene, so cleaning products containing ammonia will push the reading up. A way to ignore cleaning times still needs to be added.

7. Conclusion

A monitoring device for small home coops can be built from common parts for IDR 189,100 and installed on a working coop without bringing mains power into it. Two design choices make this possible: a MOSFET switch on the positive side, which allows the heater, the biggest power user, to be turned off between readings; and the use of the temperature measured at the same moment to correct the gas reading. Measuring the real accuracy and the real power use is the next step.

References

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The diagrams below show the wiring behind the block diagram in Fig. 1, including the component values and the two transistor switches. Where two lines cross without a black dot, they are not connected.

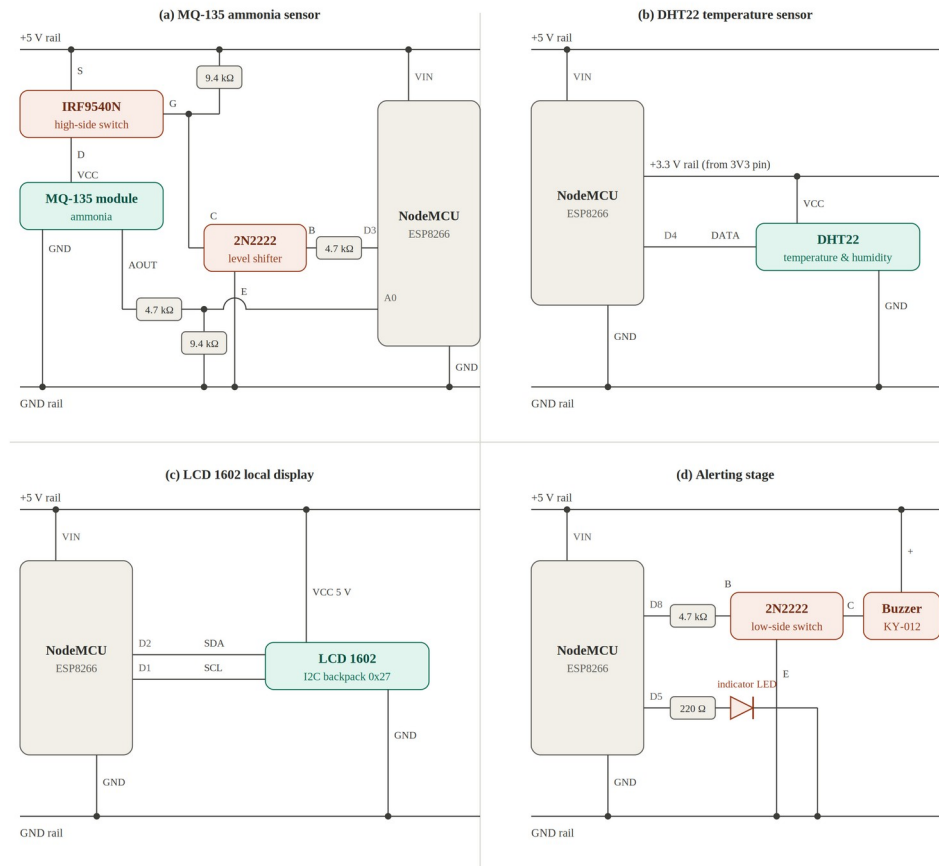


Fig. A1. Wiring of each part: (a) ammonia sensor with heater switch and voltage divider, (b) temperature and humidity sensor, (c) display, (d) warning parts.