

Improving Reading Accuracy of ACS712 Current Sensor with ATmega328 10-Bit ADC: Enhancing Resolution to 5 mA/Bit via AD620 Differential Amplifier and Kalman Filters

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ABSTRACT

The study focuses on the development of a current measuring device that incorporates the ACS712 current sensor, enhances the reading sensitivity of the ACS712 current sensor from 27 mA/bit to 5 mA/bit through the implementation of an AD620 differential amplifier, and employs a Kalman filter for improved accuracy. This increase in current uses a differential amplifier AD620. An increase in the sensitivity of the reading is carried out by utilizing the initial value of the ACS712 sensor when it has not been connected to the circuit or an offset of 512 to 0 so that 10bit ADC data can be utilized to measure 4880 mV/A so that the accuracy of reading 1-bit data is equal to 4.8 mV/mA after being given a gain of 26.5 times. The signal enhanced from the AD620 will be filtered using the Kalman filter program so that the signal generated after the increase will be stable, and the current value that has been read will be displayed on the LCD screen. Based on the analysis results, the ACS712 current sensor can effectively measure up to 5 mA/bit stably using the AD620 differential amplifier and Kalman filter.

Keywords: ACS712 Current Sensor, Kalman Filter Program, Differential Amplifier AD620, Microcontroller, Atmega328

ABSTRAK

Studi ini berfokus pada pengembangan alat pengukur arus yang menggabungkan sensor arus ACS712, meningkatkan sensitivitas pembacaan sensor arus ACS712 dari 27mA/bit menjadi 5mA/bit melalui penerapan penguat diferensial AD620, dan menggunakan filter Kalman untuk akurasi yang lebih baik. Peningkatan arus ini menggunakan *Differential Amplifier* AD620, peningkatan sensitivitas pembacaan dilakukan dengan memanfaatkan nilai awal sensor ACS712 ketika belum dihubungkan ke rangkaian atau *offset* sebesar 512 menjadi 0 agar data 10bit ADC dapat dimanfaatkan untuk mengukur 4880 mV/A, sehingga akurasi pembacaan 1bit data sama dengan 4,8 mV/mA setelah diberikan penguatan sebesar 26,5 kali. Sinyal yang telah ditingkatkan dari AD620 akan difilter menggunakan program Kalman filter, sehingga sinyal yang dihasilkan setelah dilakukan peningkatan akan stabil, nilai arus yang telah di baca akan di tampilkan pada layar LCD. Berdasarkan hasil analisis, sensor arus ACS712 dapat bekerja dengan efektif untuk mengukur hingga 5 mA/bit dengan stabil menggunakan *differential amplifier* AD620 dan Kalman filter.

Kata Kunci: Sensor Arus ACS712, Program Kalman Filter, Differential Amplifier AD620, Mikrokontroler, Atmega328



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1. Introduction

Current sensors are critical to identifying electrical parameters other than voltage sensors. Since power and electrical energy are determined by multiplying current and voltage, the power and energy characteristics cannot be estimated or measured without current data. Many current sensors are available on the market and have been used to detect electric currents, including CT (Current Transformer) sensors, Hall Effects, and

induction. The ACS712-type Hall sensor is a popular sensor that costs less than current CT sensors. The sensor operates based on the Hall effect, which is brought about by a current-carrying electric field. As a result, the sensor does not require inductors or coils, which lowers production costs. The ACS712 sensor has a large linearity and is quite sensitive, with a sensitivity of around 185 mV/A, but it cannot detect small currents, such as milliamperes. The clamp meter accuracy ranges from 1% - 2% of the measuring range [1–6]. A research on electrical measuring instruments, using the ACS712 30 Ampere sensor to read and calibrate DC and AC values using the Hall effect principle. The sensor has good reading accuracy because it contains a number of low-density linear chambers with copper tracks. This sensor measures the current moving through the copper wire inside to function [2,7,8].

The improvement method that will be carried out is to amplify the sensor output voltage using an amplifier, namely a differential amplifier. Besides being amplified, the current signal must also be filtered so that noise does not interfere with the sensor reading process. The data processing base is carried out using the Arduino microcontroller, namely as a sensor voltage reader, calibrating it to a current value and displaying it on the LCD display [9–12].

The Hall effect technology implemented by the company Allegro replaces the shunt resistor and current transformer with a sensor capable of measuring current. The term Hall Effect was known after Edwin H. Hall (1855 - 1938) discovered that if an electric current flows through a conductor placed at latitude, a strong magnetic field will produce a potential difference across the conductor at both corners of the conductor. Space Effect Sensor (Hall Effect Sensor) is a transducer that can change the magnitude of the magnetic field into electrical quantities in the form of voltage. This type of sensor operates to detect the proximity, presence, or absence of a magnetic field from an object. Hall effect allegro ACS712 is a precise sensor as an AC or DC sensor in readings [13–15].

This study uses IC AD620 as a signal amplifier to develop this utility. An affordable instrumentation amplifier IC called the AD620 only requires a resistor to adjust the gain between 1 and 10,000. The AD620 IC has low power requirements (maximum 1.3 mA), making it ideal for battery-operated and other portable applications. The AD620 is also ideal for high-accuracy systems such as balances and medical applications such as blood pressure monitoring and EKGs.

2. Method

2.1. Hardware Design

Figure 1 shows the block diagram of the device's hardware design; Figure 2 shows the system circuitry. To measure current, the power supply will send a voltage to the sensor through a resistance which will affect the current to the ACS712 sensor. The ACS712 sensor is integrated with an AD620 amplifier, followed by data transmission to an Arduino for visualization on an LCD screen. The data obtained from the ACS712 sensor undergoes Kalman filtering to minimize signal fluctuations before display.

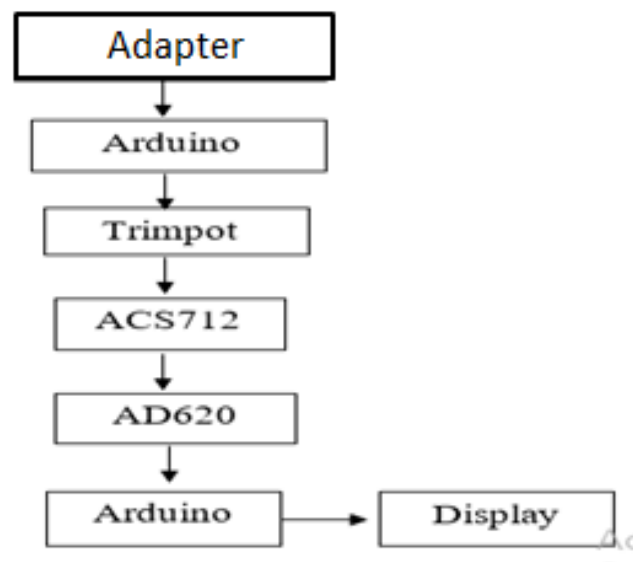


Figure 1. Block diagram of the device's hardware design.

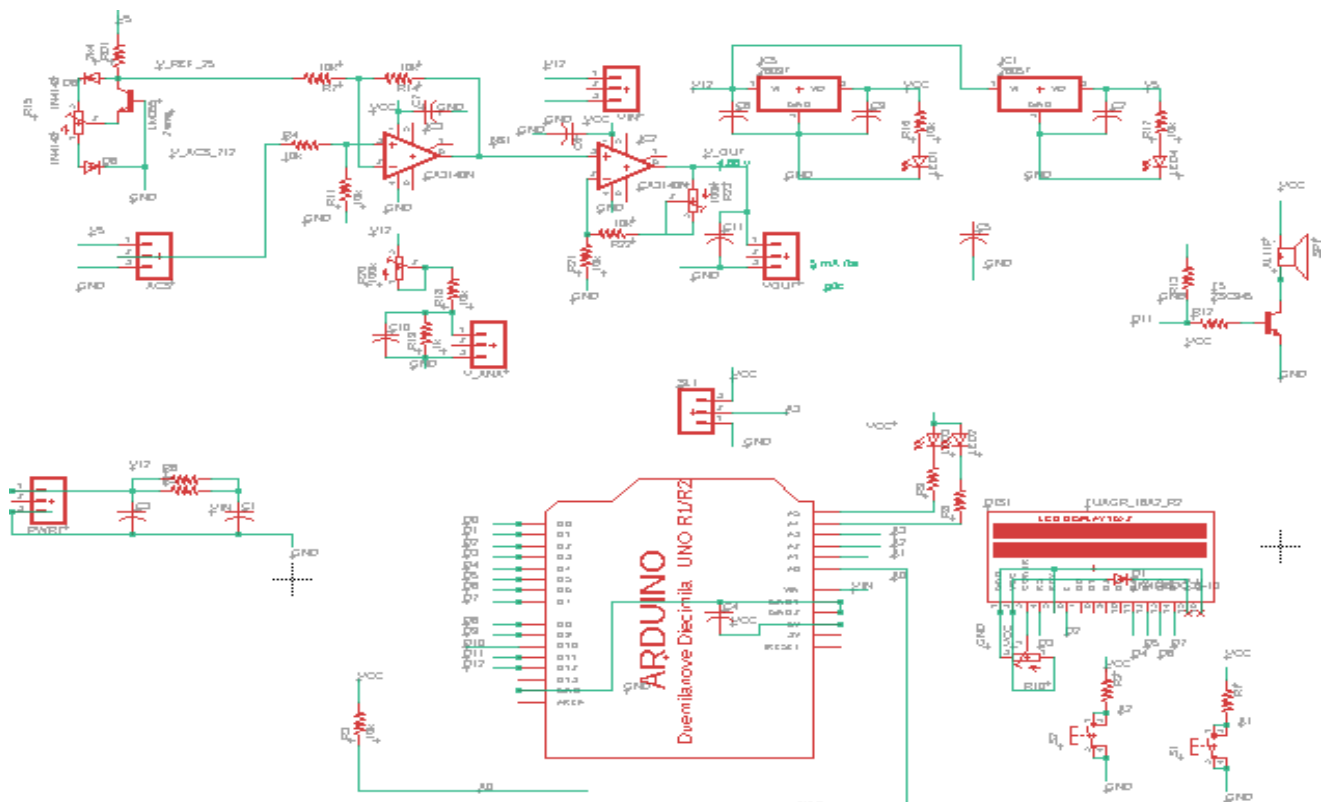


Figure 2. System circuitry of the device.

2.2. Software Design

Figure 3 shows the flowchart of the device. In this design, the microcontroller is programmed to detect the electric current flowing to a load. Thus at the start, the microcontroller will initialize it first and assign initial values to all variables before reading input. After this process, the input will be read through the analog input. The analog voltage at the input is then converted to digital data by the ADC. Digital data is converted again into a current value or calibrated. The calibration results are then sent to the output, which is the LCD.

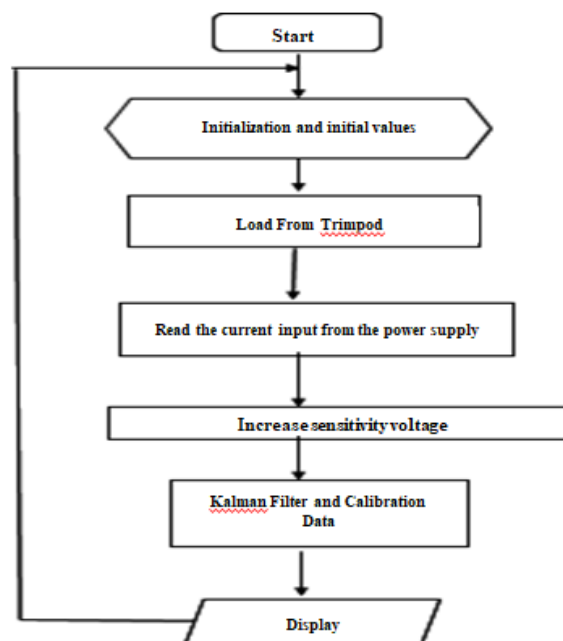


Figure 3. Flowchart of the device.

2.3. Solar Panel and Power Supply Circuit Testing

Tests are carried out to determine how much current and voltage solar panels and batteries are at the charging time; observations are carried out every 1 hour starting from 08.00-18.00 WIB. Solar panel voltage testing is carried out by directly testing the negative and positive probes of solar panels in an open circuit (Voc), while current testing is carried out by testing the current of solar panels directly without load or short circuit current (Isc). Solar panels use monocrystal type.

3. Results and Discussion

3.1. ACS712 Sensor Testing

The reading from the ACS712 current sensor is in the form of a signal analog on the Arduino analog pin, which has the analog to digital converter (ADC) with a resolution of 10 bits, presented in the value range 0 – 1023. The ACS712 sensor has an initial offset or value when the current sensor is not connected to the circuit, i.e., around 512. In this study using a current sensor version ACS712 5A. The ACS712 5A current sensor has 0.185 V sensitivity and finer resolution than any other version. Thus it can calculate the current flowing in the sensor based on equations (1).

$$I = (ADC - Offset) \times \frac{V_{reference}}{1023} \times \frac{1}{Sensitivity} \quad (1)$$

where $Offset = 510$, $V_{reference} = 5$ volt, and $sensitivity = 0.185$.

Testing of the ACS712 current sensor is carried out to test the reading of the ACS712 current sensor compared to the reading of the ammeter. The ACS712 current sensor test was carried out 7 times by varying the resistance with a variable power supply. The test results after and before calibration are shown in Table 1 and Table 2.

Table 1. Data from current sensor test results before calibration.

Testing At	Resistance (Ω)	Multimeter (A)	Sensor (A)	Δ Error (A)	% Error
1	1.0	4.22	3.03	1.19	28.19
2	1.5	3.68	2.58	1.10	29.89
3	2.0	3.16	2.43	0.75	23.10
4	2.5	2.82	2.16	0.66	31.22
5	3.0	2.46	1.76	0.70	28.45
6	3.5	2.02	1.44	0.58	28.71
7	4.0	1.77	1.36	0.41	23.16
Mean				0.76	27.53

Table 2. Data from current sensor test results after calibration.

Testing At	Resistance (Ω)	Multimeter (A)	Sensor (A)	Δ Error (A)	% Error
1	1.0	4.22	4.16	0.06	1.42
2	1.5	3.68	3.54	0.14	3.80
3	2.0	3.16	3.09	0.07	2.21
4	2.5	2.82	2.82	0	0
5	3.0	2.46	2.35	0.11	4.47
6	3.5	2.02	1.94	0.08	3.96
7	4.0	1.77	1.65	0.12	6.77
Mean				0.08	3.23

3.2. Evaluation of The Device

Figure 4 shows that when the current is in the 0 mA stage, slowly, the voltage will increase from 0 volts to 12 volts. When it reaches 12 volts, the device will try to maintain a constant voltage ranging from 0 mA to 5 mA. However, when the tool tries to maintain the voltage, there is a rise in voltage on 1 mA current; when this happens, the tool will try to lower the voltage so that when the current reaches 2 mA, the resulting voltage can be constant again.

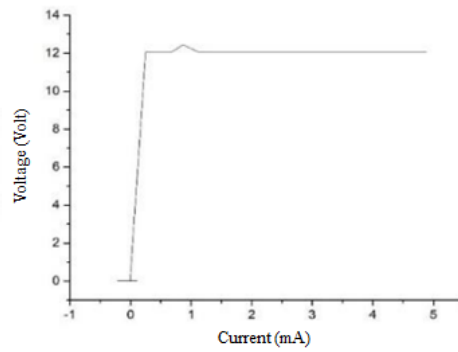


Figure 4. Test results for the device at a current of 5 mA.

Figure 5 shows that when the current is in the 0 mA stage, slowly, the voltage will rise from 0 volts up to 12 volts. When it reaches 12 volts, the device will try to maintain a constant voltage from 0 mA to 10 mA.

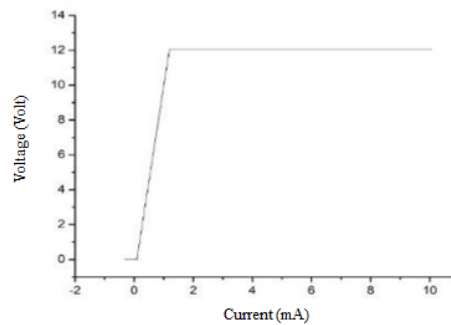


Figure 5. Test results for the device at a current of 10 mA.

Based on Figure 6, the observations at 0 mA indicate a gradual voltage increase, starting from 0 volts to 12 volts. Upon reaching 12 volts, the device maintains a consistent voltage as the current remains between 0 and 15 mA.

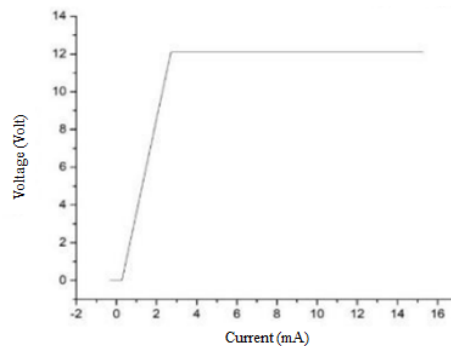


Figure 6. Test results for the device at a current of 15 mA.

Drawing insights from Figure 7, the pattern becomes evident: as the current initiates at 0 mA, the voltage incrementally ascends from 0 volts, reaching a pinnacle of 12 volts. Subsequently, the device adeptly sustains a consistent voltage range, encompassing 0 mA to 22 mA.

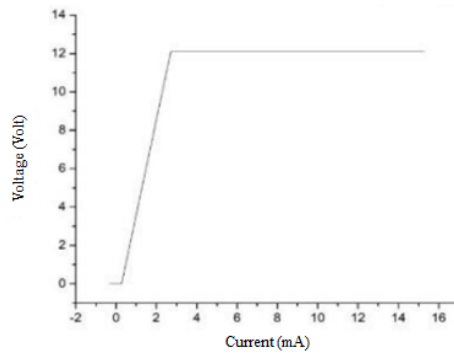


Figure 7. Test results for the device at a current of 22 mA.

In the initial state where $I = 0$, the output voltage (V_{out}) corresponds to 2.5 volts multiplied by the input voltage (V_{in}). Given that the V_{in} value is known to be 512 bits, utilizing half of the 10-bit Atmega ADC, steps are taken to enhance the accuracy of sensor readings. This enhancement involves capitalizing on the sensor's known sensitivity of 185 mV/A and using a V_{in} of 5 volts.

The calculation unfolds as follows to attain a data set of 1000 bits: $V_{in} / 1023 \cdot 5 \text{ volts} / 1023 = 4880 \text{ mV}$. Next, the input voltage data for 1000 bits is examined: $V_{in} / 1000 \cdot 4880 \text{ mV} / 1000 \text{ bits} = 4.8 \text{ mV}$. Given the goal of achieving 1 mA/bit data, the calculation proceeds: $1000 \text{ mA} / 1000 \text{ bits} = 1 \text{ mA/bit}$. This establishes the reading accuracy at 1 bit = 4.8 mV/mA. The formula is applied to determine the required amplification factor: $G = V_{in} / \text{sensitivity}$; $G = 4880 / 185$; $G = 26.5$ times. Hence, 26.5 times the initial value reinforcement is necessary to achieve the desired outcome.

4. Conclusion

The enhanced ACS712 current sensor, integrated with the AD620 differential amplifier and Kalman filter, has demonstrated robust performance. The device effectively measures currents to 5 mA/bit by finely adjusting the initial ACS712 offset from 512 to 0. This calibration facilitates current readings reaching the 1mA/bit threshold, benefiting from the AD620 amplifier's assistance. Upon mitigating the ACS712 initial offset, the 10-bit ADC enables measurement accuracy of 4880 mV/A, translating to a remarkable 4.8 mV/mA reading accuracy for each data bit. The introduced gain factor of 26.5, facilitated by the AD620 amplifier, further refines precision. Incorporating the Kalman filter into the system post-calibration minimizes signal oscillations, ensuring a stable and reliable output. This comprehensive approach underscores the successful design and deployment of a highly accurate current measuring tool.

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