MMS

Motor Monitoring System

A PROJECT BASED LEARNING

PROJECT REPORT

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ABSTRACT

This work presents a design for a comprehensive motor monitoring system employing a combined approach with infrared (IR) and Hall effect sensors. The IR sensor offers contactless detection of motor shaft rotation, providing information on motor operation and potential stalling conditions. The Hall effect sensor, strategically positioned near the motor's magnetic field, enables real-time monitoring of the magnetic field.

This combined sensor approach addresses limitations inherent in individual sensors. The IR sensor's simplicity is enhanced by the Hall effect sensor's high accuracy for magnetic field effect determination. The system design emphasizes cost-effectiveness and ease of implementation, making it suitable for various motor applications.

1. INTRODUCTION

Motors are ubiquitous in industrial automation, powering a vast array of machinery. However, their optimal performance hinges on efficient monitoring to ensure smooth operation, prevent downtime, and extend lifespan. This paper introduces a novel motor monitoring system that leverages the strengths of two complementary sensors – infrared (IR) and Hall effect – while incorporating the processing power of an 8051 microcontroller.

The IR sensor, with its non-invasive nature, provides a reliable method for detecting motor shaft rotation. This offers a crucial indication of motor operation and can trigger alerts in case of stalling or stoppage. The Hall effect sensor, strategically placed close to the motor's magnetic field, captures magnetic field effect data. This data is vital for real-time monitoring of motor status, enabling preventive maintenance and performance optimization.

The integration of these sensors with an 8051 microcontroller elevates the system's intelligence. The microcontroller acts as the heart of the system, acquiring sensor data, processing it in real-time, and generating control signals or alerts as needed.

1.1. Motivation

Motors are the workhorses of industry, powering everything from factory assembly lines to HVAC systems in buildings. However, their silent operation can mask underlying issues until they escalate into costly breakdowns and production delays. Traditional monitoring methods, often relying on manual checks or rudimentary sensors, lack the precision and comprehensiveness required for proactive motor management.

This is where the proposed intelligent motor monitoring system, integrating IR and Hall effect sensors with an 8051 microcontroller, offers a compelling solution. Here's why this system is highly motivated:

- <u>Early detection of faults</u>: By continuously monitoring motor operation (through IR sensor) and magnetic field (via Hall effect sensor), the system can identify anomalies like bearing wear, misalignment, or impending electrical faults. This enables intervention before these issues snowball into catastrophic failures.

- Improved system reliability: Early problem detection translates to prompt corrective actions, preventing unexpected equipment failures and minimizing downtime. This translates to increased production efficiency and cost savings.
- Reduced maintenance costs: Traditional reactive maintenance, where repairs occur after failures, is expensive and disruptive. The proposed system facilitates a shift towards predictive maintenance, enabling targeted servicing based on sensor data and identified issues. This reduces overall maintenance costs and extends motor lifespan.
- Enhanced safety: Unforeseen motor breakdowns can pose safety risks to personnel and equipment. The system's ability to detect anomalies early on helps prevent such situations, fostering a safer work environment.

In essence, this intelligent monitoring system is motivated by the critical need to move beyond reactive maintenance practices towards a proactive approach that ensures motor reliability, optimizes performance, minimizes downtime, and fosters a safer and more cost-effective industrial environment.

2. PROBLEM DEFINITION

2.1. Problems Faced

Traditional motor monitoring systems often rely on a single monitoring technique, leading to limitations in data acquisition and functionality. These limitations can be addressed by developing a more comprehensive monitoring system.

Current Limitations:

- Simple on/off monitoring: Traditional systems might only use limit switches or basic current monitoring to detect motor operation. This approach lacks information about motor speed and potential performance issues.
- Inaccurate speed measurement: Techniques like measuring motor current for speed estimation are indirect and prone to inaccuracies as light may be reflected back at a non-uniform motion which might detect fault at an unexpected time.
- Limited data for diagnostics: Without comprehensive data on speed and operation, diagnosing potential problems like bearing wear or impending failure becomes difficult. Also, even if we acquire the present-state data we can never predict the stage form where the fault starts to occur until we are unable to store the retrieved data.
- Reactive maintenance approach: Traditional systems often rely on failure detection instead of proactive monitoring, leading to unexpected downtime and potentially higher maintenance costs.

2.2. Critical Issues

The proposed motor monitoring system with IR and Hall effect sensors offers a robust solution. However, a potential issue arises from the environmental limitations of the IR sensor.

IR sensors rely on detecting changes in infrared radiation. This dependence creates vulnerabilities in certain environments:

- External IR interference: Strong external infrared sources, like sunlight or nearby industrial heaters, can disrupt the sensor's signal, leading to inaccurate readings or missed detections of shaft rotation.
- Dust and debris accumulation: Dust or debris on the IR sensor can obscure the signal path, potentially causing missed detections or erratic readings. This is particularly concerning in industrial settings with airborne contaminants.
- Material limitations: The effectiveness of IR sensors can be impacted by the material of the rotating shaft. Highly reflective or absorbent surfaces may not reflect infrared radiation adequately, hindering detection.

These limitations could lead to:

- False alarms: Misinterpreting external IR sources as shaft rotation, triggering unnecessary alerts or system shutdowns.
- Missed detections: Failure to detect actual shaft rotation due to dust buildup, external IR interference, or incompatible shaft material.
- Data inconsistency: Erratic sensor readings due to environmental factors can compromise the accuracy of collected data and hinder reliable motor health assessment.

This issue necessitates further investigation into:

- Calibration strategies: Exploring methods to calibrate the IR sensor for optimal performance in the target environment.
- Alternative sensor placement: Investigating alternative mounting locations for the IR sensor to minimize external IR interference.
- Sensor shielding: Researching the feasibility of implementing physical shields to mitigate external IR interference.
- Redundancy with Hall effect sensor: Exploring the possibility of using the Hall effect sensor data to confirm or validate IR sensor readings in case of ambiguity.

Addressing this environmental sensitivity of the IR sensor will ensure the robustness and reliability of the overall motor monitoring system.

3. PROJECT DESCRIPTION

3.1. Items Used

Here, we have used the 8051 microcontroller which follows the USB to UART protocol which would be making its connections to the two sensors used i.e., IR and Hall Effect sensor.

IR sensor tends to provide the resultant readings as an analogue value, whereas the hall effect sensor is a digital resultant provider which helps to retrieve the data from it much easily.

However, we use an ADC to convert the reading of IR sensor from analogue to digital which sends the reading to the 8051 microcontroller after self-clocking itself for some time of delay. We display the data to the 16x2 LCD display to represent the results.

3.2. Code Preparation and Upload

```
#include <reg51.h>

// Function Declarations
void delay(void);
void LCD_Ready(void);
void LCD_CMD(unsigned char);
void LCD_DATA(unsigned char);
void LCD_init(void);
void display_mag(unsigned char);
void display_prox(float);
void convert_display_LCD(float);

// ADC
sbit CS = P2^0;
sbit Read = P2^1;
sbit Write = P2^2;
sbit INTR = P2^3;

// Sensor
sbit mag_field = P2^4;

// LED Outputs
sbit LED_1 = P3^2;
sbit LED_2 = P3^3;

// LCD Display
sbit RS = P2^5;
sbit RW = P2^6;
```

```
sbit EN = P2^7;
sbit busy = P1^7;

// A threshold value for the IR sensor output
float threshold = 3.0;

int main(void)
{
		float value;
		unsigned char magnet;

		// LED Outputs
		LED_1 = 0;
		LED_2 = 0;

		// LCD Display
		RS = 0;
		RW = 0;
		EN = 0;
		busy = 0;
		P1 = 0x00;
		LCD_init();

		// ADC
		P0 = 0xFF;
		CS = 0;
		INTR = 1;
		Read = 1;
		Write = 1;
		mag_field = 1;

		// ADC Logic
		while(1)
		{
				Write = 0;
				Write = 1;
				while(INTR);
				Read = 0;
				value = P0*5.0/256.0;
				magnet = mag_field;
				display_mag(magnet);
				display_prox(value);
				Read = 1;
		}
		return 0;
}

void delay(void) // Delay Subroutine
{
		TMOD = 0x01;
		TL0 = 0x00;
		TH0 = 0x00;
		TR0 = 1;
		while(!TF0);
		TR0 = 0;
		TF0 = 0;
}
```

```
void LCD_Ready(void) // Subroutine to check if LCD is busy
{
	busy = 1;
	RS = 0;
	RW = 1;
	do
	{
		EN = 0;
		delay();
		EN = 1;
	}while(busy);
	busy = 0;
}

void LCD_CMD(unsigned char CMD) // Subroutine to send a command to LCD
{
	LCD_Ready();
	P1 = CMD;
	RS = 0;
	RW = 0;
	EN = 1;
	delay();
	EN = 0;
}

void LCD_DATA(unsigned char DATA) // Subroutine to send data to LCD
{
	LCD_Ready();
	P1 = DATA;
	RS = 1;
	RW = 0;
	EN = 1;
	delay();
	EN = 0;
}

void LCD_init(void) // Subroutine to initialize LCD
{
	unsigned char msg1[] = "MAG FIELD: ", msg2[] = "IR SENSOR: ", i;
	LCD_CMD(0x38);
	LCD_CMD(0x0E);
	LCD_CMD(0x01);
	LCD_CMD(0x80);
	for( i = 0 ; i < (sizeof(msg1)/sizeof(msg1[0]))-1 ; i++ )
		LCD_DATA(msg1[i]);
	LCD_CMD(0xC0);
	for( i = 0 ; i < (sizeof(msg2)/sizeof(msg2[0]))-1 ; i++ )
		LCD_DATA(msg2[i]);
}

void display_mag(unsigned char magnet) // Subroutine to display Hall Effect Sensor data on LCD
{
	LED_1 = magnet;
	LCD_CMD(0x8B);
	LCD_DATA(magnet+48);
	delay();
}
```

```
void display_prox(float value) // Subroutine to display IR Sensor data on LCD
{
	unsigned char i;
	LCD_CMD(0xCB);
	convert_display_LCD(value);
	if(value>=threshold)
	{
		LED_2 = 1;
		for(i = 0; i < 15 ; i++)
			delay();
	}
	else
	{
		LED_2 = 0;
		for(i = 0; i < 15 ; i++)
			delay();
	}
}

void convert_display_LCD(float value) // Subroutine to display a float value on LCD with 2 bit precision
{
	unsigned char INT = (unsigned char) value;
	unsigned char DEC = (unsigned char) ((value - (float)INT)*100);
	unsigned char digit1 = DEC/10, digit2 = DEC%10;
	LCD_DATA(INT+48);
	LCD_DATA('.');
	LCD_DATA(digit1+48);
	LCD_DATA(digit2+48);
}
```

After we prepare the final code for the required conditions, we need to actually dump the code to the 8051 microcontroller. In order to do this, we use an open-source software called stcgal. This software uses the CLI (Command Line Interface) to interact with STC series boards.

To actually dump the code to our board, we first need to create the .hex file of the project we're working in. This can be done quite easily using the Keil µVision IDE. After opening the project, we add only the file containing our code to the source group, go to 'Options for Target>Output', and then check the option for 'Create HEX file'. Once this is done, build the project. The .hex file should now be available in Keil's working directory.

Connect the board to the system using USB, check the COM port it's connected via using Device Manager (on Windows systems). Open a CLI and type in the following command:

stcgal -p {Name of port} {.hex File Path}

Replace the curly braces with the port name and the .hex filepath, respectively. Once the code has been dumped into the microcontroller, the USB cable can be disconnected, and the board can be powered using the actual power cable.

3.3. Circuit Diagram

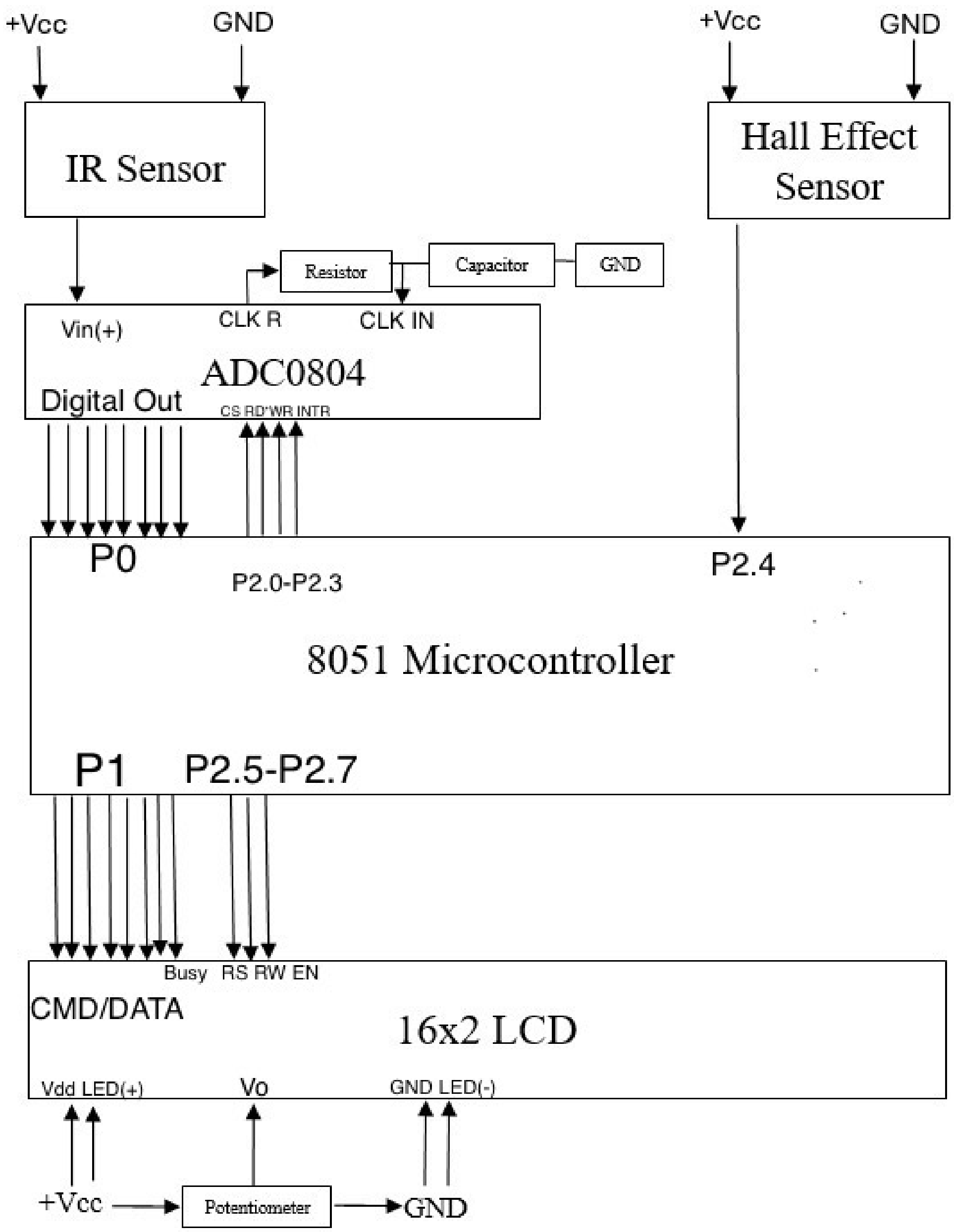

Figure 1: Block Diagram

3.4. Working Principle

By providing an input power supply to the 8051 microcontroller according to the circuit diagram connections and uploading the code with the set parameters, we can monitor various motor parameters and the light reflection distance set by the sensor's screw.

Fluctuations in the IR sensor readings indicate potential faults, suggesting disruption in obstacle detection or a break in the readings received from the ADC0804. Additionally, fault detection in the Hall Effect sensor signifies the absence of a magnetic field, prompting the LCD to display '1' for the magnetic field reading, while nominally displaying '0'.

4. RESULT

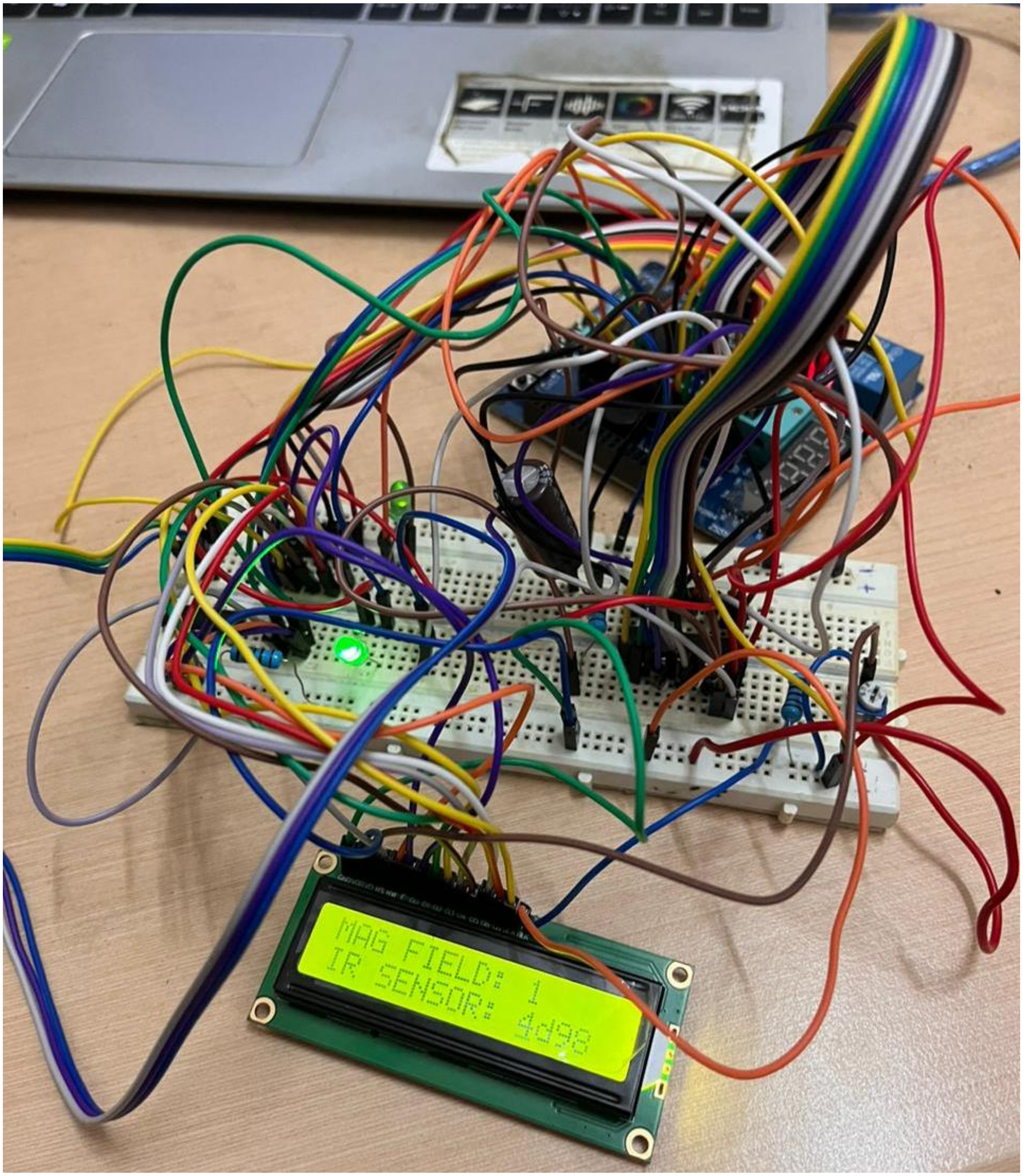

Figure 2: System Output

CONCLUSION

This paper presented a novel motor monitoring system that leverages the strengths of infrared (IR) and Hall effect sensors, along with the processing power of an 8051 microcontroller. The system offers a comprehensive and cost-effective solution for ensuring optimal motor performance and preventing unexpected downtime.

The IR sensor provides contactless detection of shaft rotation, enabling the system to identify motor operation and potential stalling conditions. The Hall effect sensor, strategically positioned, delivers magnetic effect data for real-time monitoring of motor. The integration of these sensors with an 8051 microcontroller elevates the system's intelligence by facilitating data acquisition, processing, and generation of control signals or alerts.

This combined sensor approach addresses limitations inherent in individual sensors. The system design prioritizes cost-effectiveness and ease of implementation, making it suitable for various motor applications across industries.

The potential environmental limitations of the IR sensor were acknowledged, emphasizing the need for further investigation into calibration strategies, alternative sensor placement, and redundancy measures with the Hall effect sensor. Addressing these limitations will ensure the system's robustness and reliability in diverse environments.

In conclusion, this motor monitoring system presents a significant advancement in ensuring motor health and optimizing performance. The system's ability to detect faults proactively, coupled with its data-driven approach, empowers informed decision-making for preventive maintenance and extended motor lifespan. The potential for further development and integration with additional functionalities promises an even more comprehensive and intelligent solution for motor control and monitoring in the years to come.

REFERENCES

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- stcgal - https://github.com/grigorig/stcgal