

Electrical Equipment Protection Using Thermal Camera Mounted on a Quadcopter

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Abstract: In this paper we have explained how we constructed a quadcopter using Arduino Uno. It is made using BLDC motors, Electronic Speed Controller (ESC) and gyroscope. Now the quadcopter setup is equipped with a thermal camera. It uses the concept of temperature mapping to find heat related issues of any instrument or device. Image processing toolbox in MATLAB is used to analyse a thermogram, through which a CCT is obtained. This CCT is thus used to identify the temperature of the object, i.e. overheated or normal condition. Any abnormal temperature detected can be used to trigger the protective systems to turn

Keywords- Quadcopter, Arduino UNO, Matlab, OV 7670, Thermal imaging, Thermogram, Correlated Color Temperature

1. INTRODUCTION:

Often we come across parts of an equipment where human access is difficult or dangerous. Focussing on this aspect a research is done to get the temperature of electrical equipment by thermal imaging using a drone equipped with a thermal camera. A quadcopter is an aerial vehicle that uses four rotors for stabilized flight.[1]-[2] Unlike most aerial vehicles, the quadcopter is capable of achieving vertical flight in a much stable condition. The quadcopter does not face issues of torque that are generally faced by helicopters. More over the cyclic design of the quadcopter makes it easier to design and maintain. With advancements in technology the use of quadcopter in various areas have been increasing. With compact and simple design, it is easy to construct and manoeuvre. During flight it undergoes three types of movements namely pitch, yaw, roll. It is controlled by various flight controller boards. In this project we are using ARDUINO UNO R3(ATMEGA328P) MICRO CONTROLLER as flight controller board. It is controls various electronic devices like ESC, BLDC MOTOR, INERTIAL MEASURING UNIT (MPU6050). This drone is now equipped with a thermal camera (OV7670).[4] It is interfaced with Arduino UNO r3 and is communicated using 2C protocol and the thermograms obtained will be analysed using IMAGE PROCESSING TOOL

BOX in MATLAB to obtain the HISTOGRAM of the thermogram and CORRELATED COLOR TEMPERATURE(CCT) which gives the temperature of the object which can then be protected by taking protective measures either by switching on the cooling systems or by isolating the overheated electrical equipment by opening the circuit breaker or isolator connected to it.[10]

2. BASIC STRUCTURE OF A QUADCOPTER:-

A quadcopter consists of four motors evenly distributed along the quadcopter frame. Two pusher rotor motors rotate in a clockwise direction and other two motors rotate in a counter clockwise direction using puller rotors. Each motor produces a thrust and torque about the centre of the quadcopter. The net torque about the centre of the quadcopter is ideally zero, due to the opposite spinning directions of the motors, producing zero angular acceleration. Vertical lift-off force is obtained using the same amount of throttle and by increasing its speed. It is also used to Gravitational force and quadcopter begins to rise in altitude. [5]

Quadcopter in general has 3 movements namely

1. Pitch movement
2. Yaw movement
3. Raw movement

2.1.Pitch movement:

Pitch is provided by increasing (or) decreasing the speed of the pusher rotor motors. This causes the quadcopter to turn along horizontal direction. The overall vertical thrust is the same as hovering due to the puller motor. Hence only pitch angle acceleration is changed. This is also called side to side movement. It is called elevator control movement.

2.2.Roll movement:

Roll is provided by increasing (or) decreasing the speed of the puller rotor motors. This causes the quadcopter to turn along vertical direction. The overall vertical thrust is the same as hovering due to pusher rotor motors. Hence only roll angle acceleration is changed. This is also called front to back (or) back to front movement. It is called aileron control movement.

2.3.Yaw movement:

Yaw is provided by increasing (or) decreasing the speed of the pusher rotor motors (or) by increasing (or) decreasing the speed of the puller rotor motors. This causes the quadcopter to turn along its vertical axis in the direction of the stronger spinning rotors. the corresponding rotors are less than the forces created by the left and right rotors. The quadcopter rotates in the same direction because of difference in torque produced as the faster spinning rotors. Around vertical axis movement is yaw movement. It is rudder control movement.

All the movements are signals given by flight controller boards. So many flight controller boards like Arduino, kk 2.2, apm board, nazi decoder etc.

Here we are using an atmega 328P arduino microcontroller as flight controller board.

3.ATMEGA328P:

It is a micro controller which can be programmed to perform certain tasks in order to obtain the required output.

It is a 28-pin micro controller with on board analog to digital converters, analog input pins, digital output pins, pulse width modulation pins, serial communication pins (transmitter, receiver pins), interrupt pins, used for I2C and SPI communication, voltage and ground pins.[10]

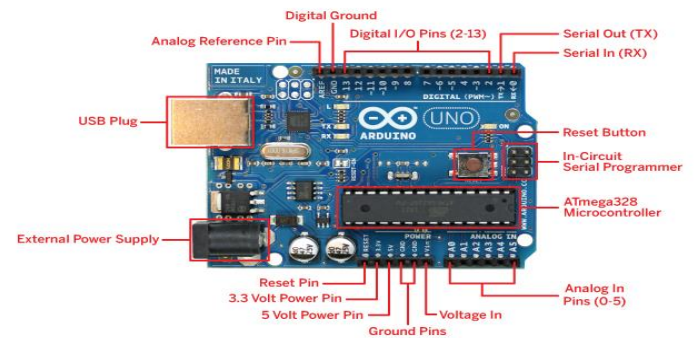


Fig1: Arduino UNO

It is programmed and mounted on the frame along with required components that are used to produce required signals. The required components are

1. BLDC motor
2. Electronic Speed Controller
3. Transmitter-Receiver pair
4. Gyro scope (or) inertial measuring unit

3.1.BLDC motor:

It is a motor that has electromagnet in its stator and permanent magnet in its armature (or) rotor. Bldc motors are known as electronically commutated motors (or) synchronous dc motors. It works on the principle of Lorentz force as conventional dc motor. In case of bldc motor stator has current carrying conductors. when these coils are switched electrically, it starts producing uniform air gap field. Voltage waveform is alternating due to switching supply. The forces of interactions produced between rotor and stator make the rotor rotate. The motor produces torque because of development of attractive and repulsive forces and make it rotate in clockwise direction.

3.2.Electronic speed controller:

It is an electronic component used for commutation of bldc motors. It is used to convert dc supply to ac. It provides good anti jamming capability for micro controller unit. It sends control signal to motor according to the operation of tx-rx pair.

3.3.Gyroscope (mpu 6050):

A gyroscope is used to measure or maintain orientation and the angular velocity. The IMU (Inertia Measurement Unit) sensor used is the mpu 6050 commonly used in self-balancing robots, smartphones, UAVs and more. The output values are generally in angles to determine the position of an object in a given space. This IMU sensor is a six-axis sensor. A six-axis sensor gives six outputs-3 each from the inbuilt accelerometer and gyroscope. It is based on MEMS (micro electro mechanical systems) technology. The gyroscope

and the accelerometer are embedded on a single chip.[5]

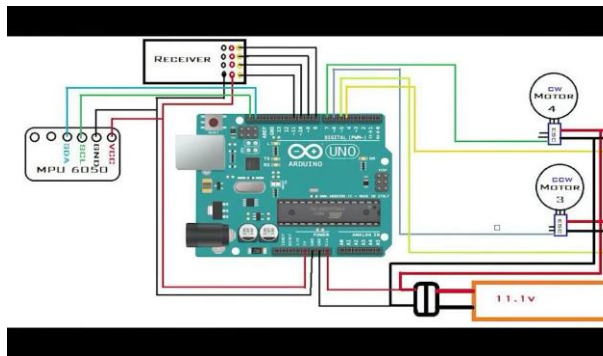


Fig 2: circuit diagram of a quadcopter



Fig 3: Quadcopter used in the project

4. ADVANTAGES OF QUADCOPTER

1. The mechanical simplicity of a quadcopter makes it extremely useful. The entire control is taken care of by the electronic stabilization.
2. With a proper electronic stabilization system, a quadcopter can have a very fine control.
3. The lack of an anti-torque system makes it quite agile in its movement in all directions.
4. For our project this is very beneficial because such characteristics makes it favourable for our thermal sensor control.

5. THERMAL IMAGE SENSING:

Every object in the universe emits few amounts of energy as heat signatures in the form of infrared rays. The hotter the object the more is the infrared energy emitted and vice versa.

It is a method by which objects are scanned using a thermal camera or thermal scanner or infrared

camera. These devices essentially are heat sensors which senses minute temperature difference of a particular object and the output is displayed in the form electronic images known as THERMOGRAM. These devices also sense heat signatures of smoke, fog etc. It gives information about temperature difference around a particular object by collecting infrared radiations around it. This process of analysing heat signatures is known as THERMOGRAPHY.

In general, the images produced by these devices are cooled and uncooled type i.e., grey coloured images. But few devices add colour to the image. The depth of the colour at a certain point indicates the temperature difference at that point. The obtained temperature is called CORRELATED COLOR TEMPERATURE (CCT).[9]

APPLICATIONS:

Thermal imaging is a novel idea and thermal imagers are initially developed for military use for surveillance and rescue purpose. Now a days the use of thermal imagers has been increased and now its usage is entrenched in various fields. The major applications are as follows.

1. In industries to check the heat signatures and collateral damage of internal parts of the machinery that is being used
2. In power sector to check the overheating of insulators and joints to avoid
3. Night vision cameras for security purpose
4. Due to their ability to track objects at a longer distance it is employed at borders of the states or countries especially at hills or mountains where continuous monitoring is not possible
5. It has wide range of applications in medicine as well.
6. It is used with *unmanned aerial vehicles and drones* for aerial thermography

Thermography these days is also being implemented in protecting electrical equipment by thermal scanning of the equipment for any overheating or damage of any internal parts

In this project we have developed the idea of thermography using drones.

Interfacing OV7670 and ARDUINO UNO R3 [3]:

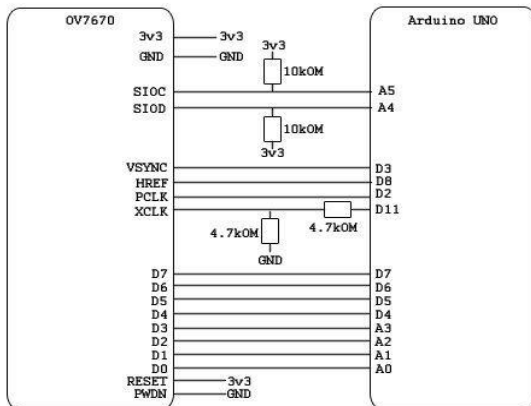


Fig 4: connections between the Arduino and the OV7670

OV7670 is a camera module which can be used for capturing the heat signatures of any object in the form of electronic images known as *thermogram*.

It has inbuilt digital signal processor, analog signal processor, analog to digital converter, image scaler.

OV7670 module is an ic chip having 16 pins. They are

1. Vcc(3.3v supply),ground(GND)
2. Serial interface clock and data I/O (SCL and SDA)
3. Vsync (active frame),Href(active pixels)
4. PCLK(pixel clock from module),XCLK(master clock into module)
5. Digital output pins(D7-D0)

SCL: Serial interface clock (SCL) is a clock line which synchronizes the data transfer

SDA: Serial interface data (SDA) is a data line which carries data. It is bi-directional.

The two lines are used for I2C COMMUNICATION. Pull up resistors are connected to both the lines. These lines are hence called OPEN-DRAIN lines. On the Arduino uno these two pins are analog input pins(A4,A5)[3]

5.1. I2C Communication with Protocol:

It is a very popularly implemented communication by electronic sensors. It is done by two lines viz SCL and SDA. This is mainly implemented when it is required to communicate between master and multiple slave devices.

5.2. Communication Protocol:

It uses 8 bits sequence for the transfer of the data from one device to another. After each 8bit

sequence the micro controller gives acknowledgement. When the device encounters START condition the first 8bit sequence indicates address of the slave and a acknowledgement bit. The next 8bit sequence indicates address of internal register of the slave. Next sequence is used to send the data and it ends when it encounters STOP condition.[4]

The most significant bit(MSB) indicates whether the master has to READ the data from SLAVE or it has to WRITE the data to the slave. Acknowledgement bits indicates whether the slave has received previous sequence or not.

Sensors That Implement I2C Protocol for Transfer of Data

1. Accelerometer (ADXL345 etc..)
2. Gyroscope (MPU-6050, ML3G4200D, etc..)
3. Camera modules (OV7670, ARDUCAM etc..)
4. Pressure and Thermal sensors.

5.3.1. HREF: It is known as horizontal reference. It indicates that one of the available frames is transferred from slave to master. This is a special signal that goes from sensor module to sensor interface. HREF indicates the start of a new line of pixels when it goes LOW. Data is available on data lines, when HREF is HIGH. The data transferred will be sampled only when HREF IS HIGH.

5.3.2. VSYNC: It is known as vertical sync (or) vertical reference. It is a type of signal which when HIGH indicates the end of current frame i.e., the entire data in the lines is transmitted and when the signal is low it indicates the start of new frame.

5.3.3. PCLK: It is known as pixel clock. It is output clock which is used to clock OV7670 device. The clock frequency determines the frames per second (fps). The frequency range of PCLK is 10MHz-48MHz. 12MHz produces 15 fps and 24MHz produces 30 fps. In general PIXEL CLOCK and SYSTEM CLOCK have same frequency. But in order to get different frames per second PCLK must be varied by PHASE LOCKED LOOP GENERATOR. PLL generator ids used to create a frequency range of 10MHz-25MHz.

XCLK: It is known as system clock input. To get any data out of OV7670 clock signal must be given to xclk pin. When the microcontroller unit is given

with system clock signal to xclk pin it drives the pins VSYNC, HREF, DIGITAL PINS (D0-D7). The clock must have frequency between 10MHz-48MHz.

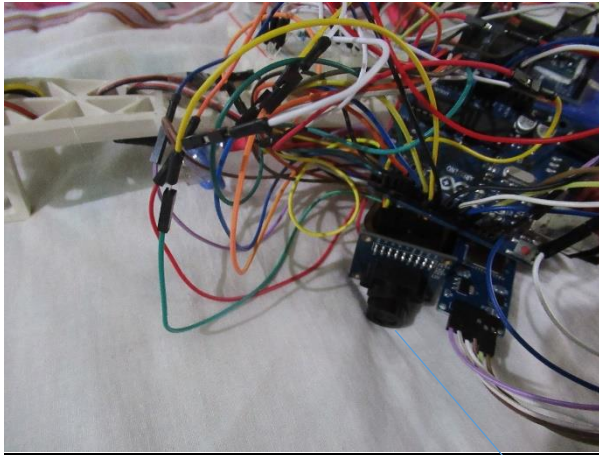


Fig 5: the camera set up on the quadcopter

OV7670

6. WORKING:

The module is given with a power supply of 3.3 volts and external clock for XCLK pin. It is mainly developed for data acquisition i.e., images and processing of thermograms based on TTL or I2C COMMUNICATION PROTOCOLS. By TTL interfacing it is convenient to store data to computer using USB cable through UNIVERSAL ASYNCHRONOUS RECEIVER/TRANSMITTER SERIAL PORT and it is easy to view images.

The OV7670 sends the data in **parallel synchronous format**. This is done when XCLK is given with clock frequency. The data in the data lines must be sampled at rising edge of the PCLK signal. This is done only at the *rising edge of HREF SIGNAL and falling edge of VSYNC SIGNAL*.

The pixel width and frame width of OV7670 is (640 x 480). 640 pixels can be captured when HREF is high. 480 frames can be captured when VSYNC is low.

In order to communicate, unique address of the specific device must be known.

The obtained thermograms are analysed in Matlab and histogram is obtained.

The pixel density of each pixel in the obtained thermograph is taken and average is taken in order to get average pixel density

Correlated color temperature (cct) is calculated using the formula:-

$$CCT=449n^3+3525n^2+6823.3n+5520.33(\text{kelvin})$$

$$\text{where } n = \frac{(0.23881)R+(0.25499)G+(-0.58291)B}{(0.11109)R+(-0.85406)G+(0.52289)B}$$

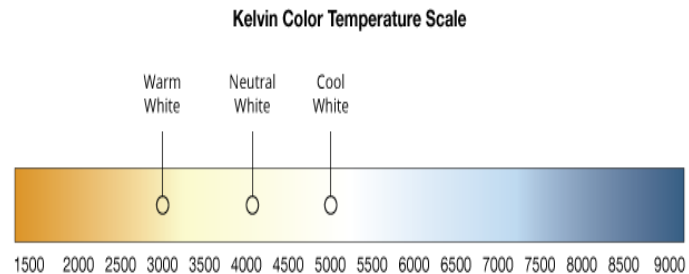


Fig 6: color scale

The more is the kelvin value the less is the temperature.[7]

Maximum storage temperature: -40 to +95 degree Celsius[5]

Supply voltages

1. DC supply voltage-analog: 2.45V to 4.5V
2. DC supply voltage-digital: 1.62V to 3V
3. DC voltage-I/O POWER: 1.7V-4.5V.
4. INPUT clock frequency: 10MHz-48MHz
5. PIXEL clock frequency: 10MHz-48 MHz

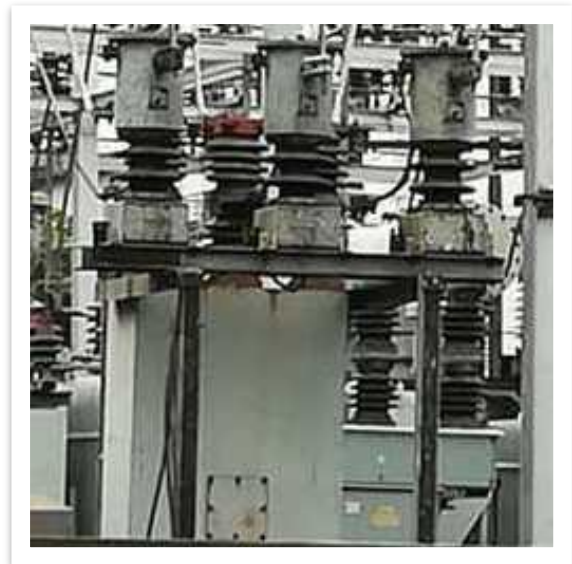


Fig 7: Original Image

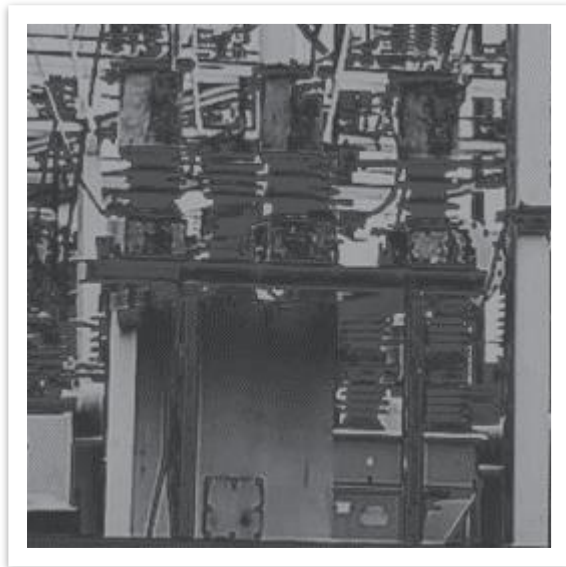


Fig: The figure above shows an inactive transformer taken by the OV7670

6.1. Experimental observations:

From the image obtained temperatures are calculated by getting R, G, and B values from Matlab. Then temperature is calculated using:-

$$CCT=449n^3+3525n^2+6823.3n+5520.33(\text{kelvin})$$

$$\text{Where } n = \frac{(0.23881)R + (0.25499)G + (-0.58291)B}{(0.11109)R + (-0.85406)G + (0.52289)B}$$

The maximum and minimum R, G and B are observed to be

Maximum Values Are R=169, G=160, B=155

Minimum Values Are R=73, G=76, B=79

The Observed Temperatures Are 7450.399(kelvin) for maximum values, 10937.329(kelvin)

For minimum values of R, G, B and the temperature range is observed to 7450.399-10937.329(kelvin)

It is compared with the scale above shown and it is observed that there is no overheating.

6.2. Future developments:

THIS can be further extended to make it wireless using Wi-Fi module or Bluetooth module so that images can be analysed when they are taken and control measures can be taken.

7. CONCLUSION:

The thermal camera has been mounted on the Quadcopter and the images of a transformer are

taken after flying it to a transformer. From the image captured R, G, B values are obtained using MATLAB. The minimum and maximum set of R, G, B values are taken and temperature in KELVIN is calculated. It is compared with KELVIN TEMPERATURE SCALE to know whether the temperature is high or low

8. FUTURE DEVELOPMENT:

THIS can be further extended to make it wireless using wi-fi module or Bluetooth module so that images can be analysed when they are taken and control measures can be taken.

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