Binford ThermDetector 3000

Coal Mine Fire Detection System

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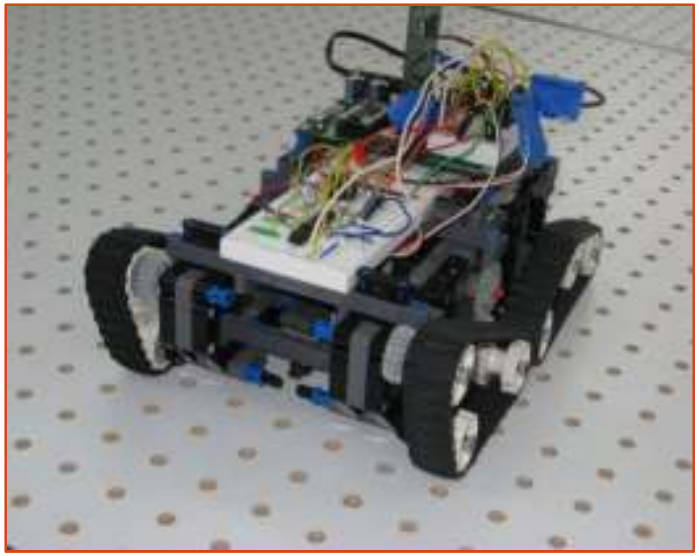


Overview

- Introduction
- Objective
- Mechanical Design
- Electronic Circuits
- Code
- Bill of Materials & Prototype Cost
- Advantages & Disadvantages
- Conclusion

Introduction: Coal Mine Fires

- Coal mine fires are burning deposits of coal.
- Either human-induced or a result of natural occurrence
- Human induced:
  - Ignition due to mining operations
- Naturally occurring:
  - Lightning
  - Forest Fires
  - Spontaneous combustion from heat, sun, water vapor
- Most extreme case: Coal Mine Fire lasting for over 30 years

Introduction: Danger to Humans

- Various gases can be emitted such as:
  - Carbon Monoxide (CO)
  - Carbon Dioxide (CO2)
  - Methane (CH4)
  - Nitrous Oxides (N2O)
  - Sulfur Dioxide (SO2)
- Quality of life is a concern
- The combination of fire burning beneath the surface of the earth, and gases leaking out to the habitation above can be a risk for all human life.

Introduction: Affecting Quality of Life

- Coal Mine Fires can affect air, water, and the food supply of the communities above it.
- Especially true for coal dependent nations such as China, or coal dependent towns such as Centralia, PA.

Objective

- Creation of the Binford ThermDetector 3000
- Fully autonomous robot to traverse a given plot of land
- Takes temperatures at each point of the field
- Send temperatures via Bluetooth to generate a heatmap
- Employ a warning system to alert locals of coal mine fires

Mechanical Design: Servomotors

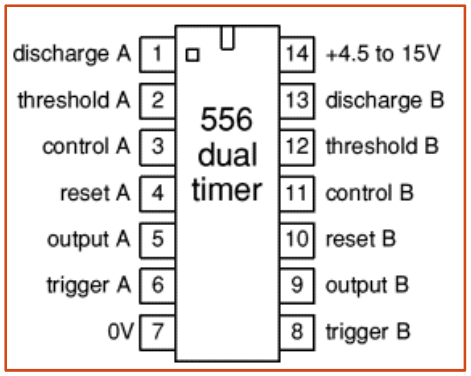
- Two Parallax (Futaba) continuous rotation servomotors
- Mounted on Lego chassis
- Servo motor was modified to allow easy switching of gears
  - Epoxy applied to attach Lego axle onto servo head
- Allows for individual control and central axis turning

Mechanical Design: Use of Treads

- Ease of Movement
- Consistent turning
- Economical:
  - Only require two motors to control turning, forward and backward movement

Electronic Circuits: Warning System

- Components:
  - 556 Timer- Dual 555 timer
    - Each half represents one 555 timer
    - Share a common ground and Vdd
  - LED- visual warning
  - Piezospeaker- auditory warning
- The Siren Dilemma
  - Speaker is audible, LED blinking is too fast
    - Speaker needs to be at >3000 Hz
  - LED blinking is visible, speaker is low



Electronic Circuits: Warning System

- The Solution: Circuiting
  - Speaker "half"- produces a high frequency output
  - LED "half"- produces a low frequency output to display visual
  - Output of LED "half" controls the rate of Speaker "half"
    - Takes the high frequency speaker output and "chops" it
- LED blinking is visible AND Speaker is audible
- Both are in astable mode at the same frequency

Electronic Circuits: Warning System

- Finding the Values

$$t_{high} = 0.693R_2C \Rightarrow R_2 = \frac{t_{high}}{0.693C} = \frac{100ms}{0.693 * 10{,}000nF} = 14430$$

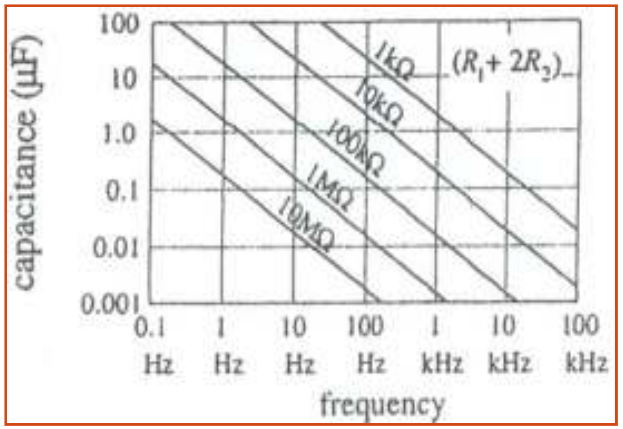
R_2 *is chosen to be* $15k\Omega$

For LED

$$t_{low} = 0.693(R_1 + R_2)C \Rightarrow R_1 = \frac{t_{low}}{0.693C} - R_2 = \frac{200ms}{0.693 * 10{,}000nF} - 15{,}000 = 13860$$

R_1 *is chosen to be* $10k\Omega$

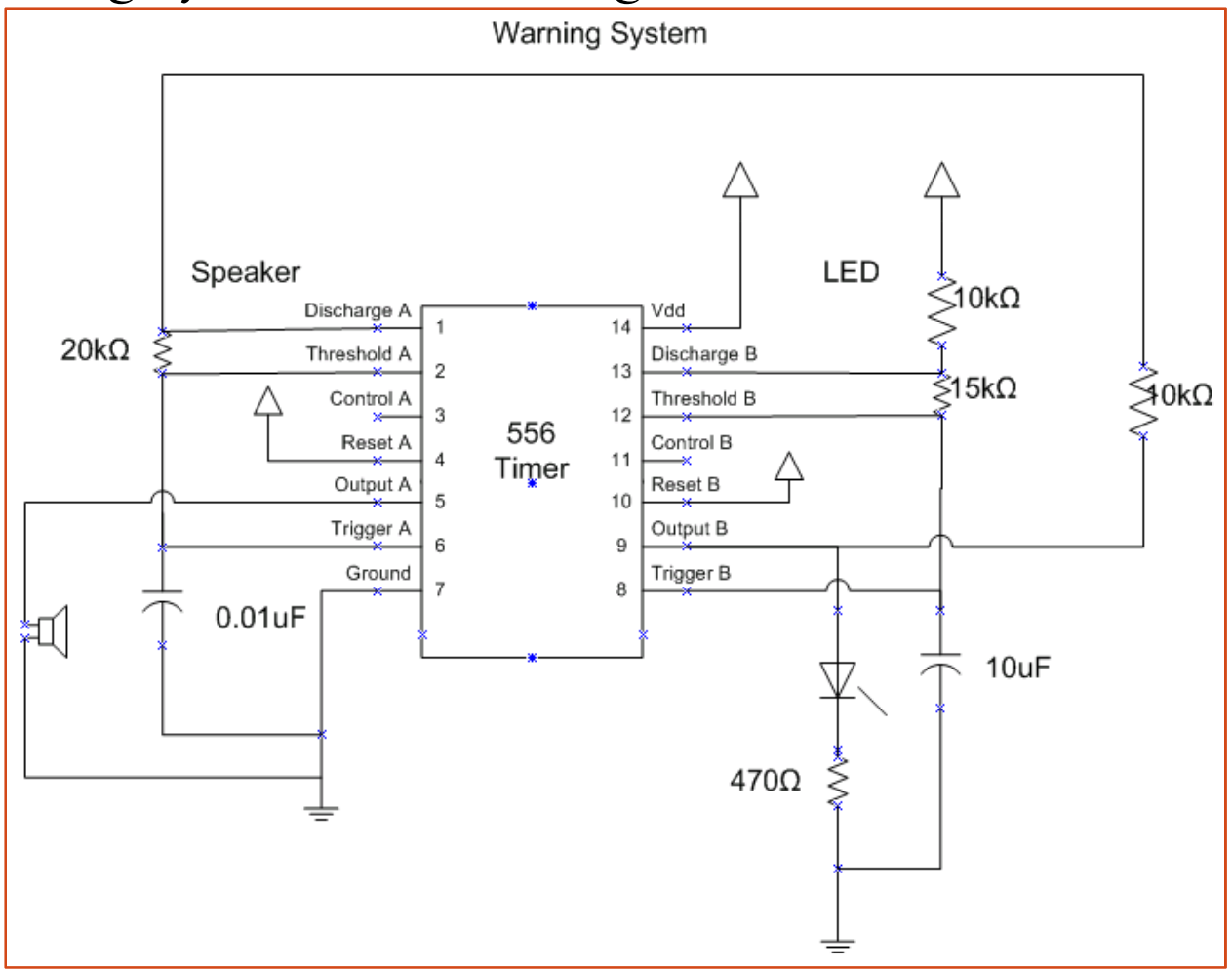
$$f = \frac{1}{t_{high} + t_{low}} = \frac{1}{0.693C(R_1 + 2R_2)} = \frac{1}{(0.693)(10{,}000nF)(10k\Omega + 2 * 15k\Omega} = 3.6Hz$$



For Speaker

Electronic Circuits: Warning System

- Warning System Circuit Diagram



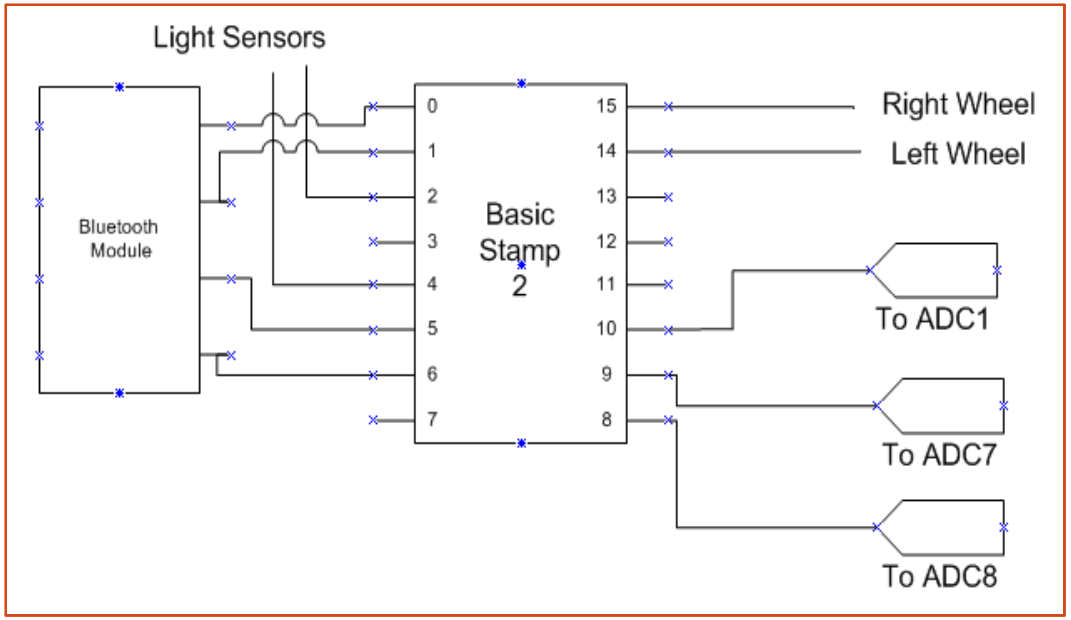
Electronic Circuits: Navigational

- Use of QRD1114 infrared(IR) reflective sensor
- Can be analog or digital
  - Analog- detects ranges of grey or
  - Digital- detects either white or black
- Why?
  - GPS cannot be used on this scale (2m)
  - Compass module is too sensitive to magnetism
- Mapping area of 80cm x 156cm
- Black borders allow light sensors to stop
- Simple movements to retrieve data

Electronic Circuits: Navigational

- The Map
- Mapping area of 80cm x 156cm
- Pegboard holes necessitate use of analog mode
- Black borders allow light sensors to stop
- Simple movements to retrieve data
  - Analogous to lawn-mowing sweeping pattern

Electronic Circuits: Navigational



Electronic Circuits: Temperature

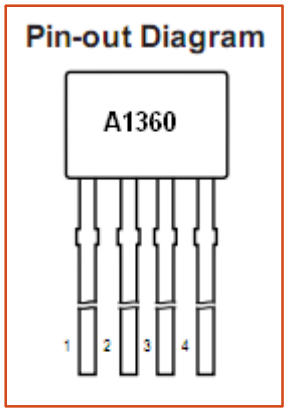
- Use of MLX90614 Infrared Thermometer Module (90° FOV) for surface temperature readings
- Digital temperature sensor
- Serial interface for easy connection
- Placed 1.5cm above the surface to allow temperature readings in a 3cm radius
- Use of pegboard to allow even temperature distribution
- Temperatures are recorded and mapped onto a heat map

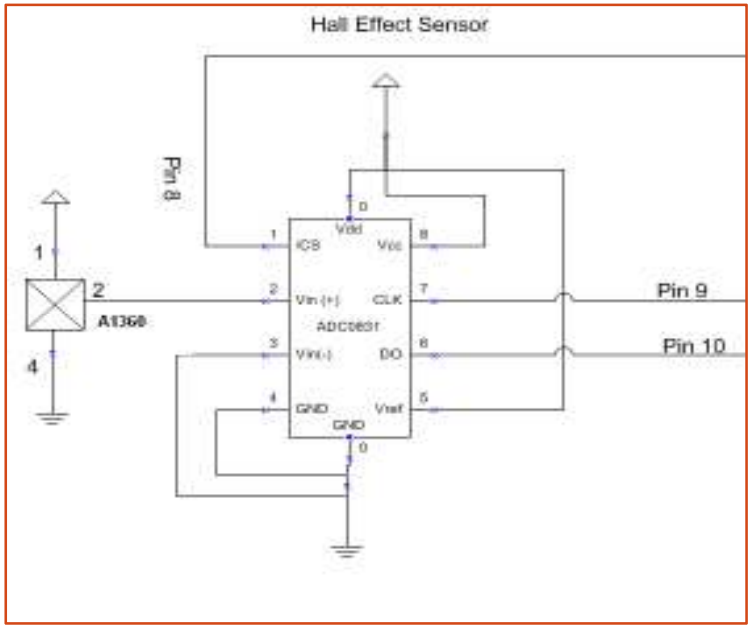
Electronic Circuits: Hall Effect Sensor

- Allego A1360 Linear Hall-effect sensor was used in connection with an AD0831 A/D Converter
- AD0831 IC allows analog voltage to be converted to digital
- Why?
  - High temperatures affect the magnetic properties of rocks
  - Hall Effect Sensor is utilized to detect these changes

Electronic Circuits: Hall Effect Sensor

- Hall Effect Sensor Circuit Diagram





Code

- Navigation-
  - Handles movement across map by conditional statements
- Temperature Readings
  - Temperature is taken from sensors
- Warning System
  - Alarm goes off when high heat or magnetism is found
- Bluetooth interfacing
  - Transmits data wireless to the Bluetooth
- Heat Map Generation
  - Takes temperature readings and plots them onto a heat map
  - May be overlayed on Google Maps

Bill of Materials

Bill of Materials: Prototype			
Item	Quantity	Cost	Total
Basic Stamp 2 Module	1	$49.00	$49.00
Board of Education Development Board (USB)	1	$69.99	$69.99
Parallax (Futaba) continuous rotation servomotors	2	$12.99	$25.98
QRD1114 infrared(IR) reflective sensor	2	$5.99	$11.98
MLX90614 Infrared Thermometer Module (90° FOV)	1	$39.99	$39.99
EmbeddedBlue Transceiver AppMod	1	$69.99	$69.99
556 Timer	1	$1.99	$1.99
Allegro A1360 Linear Hall-effect sensor	1	$2.57	$2.57
ADC0831 A2D converter	1	$5.99	$5.99
Lego Parts	1	$20.00	$20.00
Various electrical components (LEDs, Capacitors, Resistors, wires, etc)	1	$30.00	$30.00
Battery holder	1	$1.99	$1.99
Pegboard Map	1	$20.00	$20.00
Total Cost			**$349.47**

Bill of Materials: Mass Production Cost

Bill of Materials: Cost for Mass Production (100 units)			
Item	Quantity	Cost	Total
Basic Stamp 2 Module	1	$39.20	$39.20
Board of Education Development Board (USB)	1	$55.99	$55.99
Parallax (Futaba) continuous rotation servomotors	2	$11.69	$23.38
QRD1114 infrared(IR) reflective sensor	2	$5.99	$11.98
MLX90614 Infrared Thermometer Module (90° FOV)	1	$39.99	$39.99
EmbeddedBlue Transceiver AppMod	1	$69.99	$69.99
556 Timer	1	$1.99	$1.99
Allegro A1360 Linear Hall-effect sensor	1	$1.60	$1.60
ADC0831 A2D converter	1	$4.79	$4.79
Lego Parts	1	$20.00	$20.00
Various electrical components (LEDs, Capacitors, Resistors, wires, etc)	1	$30.00	$30.00
Battery holder	1	$1.99	$1.99
Total Cost			**$300.90**

Advantages

- Treads allow ease of movement through inclines and point turning
- Hall Effect Sensor is a novel method to find heat sources produced by rocks through magnetism
- Tightly, integrated system reduces cost and wasted space
- Warns locals

Problems Encountered

- GPS resolution is too large (2m)
- Iterations of map
  - Gradient- streaks caused imperfections with readings
  - Line following- navigational logic conflicted
  - Boundaries- low amounts of error
- Gas sensor
  - Not much sensitivity for gas
  - Would not be able to discern one gas from another

Conclusion

- Binford ThermDetector 3000 allows for
  - Transversal of land
  - Wireless transmission of data for quick analysis
  - Heat map shows areas of high danger
  - Magnetism uses novel method to detect coal mine fires
- Design process is never ending