Circuit 1

The circuit diagram of Circuit 1 is shown in the figure below. Circuit 1 is responsible for generating a square wave of 60 kHz on the guide-wire.

|  |  |
| --- | --- |
|  |  |

**Figure 1.** Frequency generator circuit.

Note that the Arduino programming is presented in detail later in Section 2.10 of this paper. The Arduino's D3 port generated a square wave of 60 Hz to the base of the TIP transistor 122 which was connected to a 10 kΩ current-limiting resistor. The current was thus amplified and generated an average current of 0.35 A through the resistor of the collector which was connected to the guide-wire. A voltage regulator integrated circuit (IC) was used to regulate the 12 V supply voltage to a voltage of 5 V required for the operation of the Arduino NANO. The figure below shows the layout of the circuit board generated in the Proteus Ares software package, used for creating the circuit boards used in the study.

|  |  |
| --- | --- |
|  |  |

**Figure 2.** Circuit layout shown in the Proteus software package.

The final circuit is shown in the figure below:

|  |  |
| --- | --- |
|  |  |

**Figure 3.** Final circuit.

As can be seen, the circuit was fixed to the computer power supply generating 12 V and 100 W power. When the guide-wire was connected to this circuit, a pulsating current was generated in the wire.

Circuit 2

Circuit 2 was responsible for amplifying the signal from the coils. This signal was a sine wave of voltage created by the magnetic field generated by the pulsating square wave current that ran through the guide-wire. This circuit was also responsible for rectifying the coil signal voltage and sending an analog signal to the microcontroller. The microcontroller in turn processed and determined the distance from Coils 1 and 2 to the guide-wire.

This circuit was composed of an amplifier stage achieved through the use of the amplifier circuit TDA2003. However, this amplifier required extra components such as resistors and capacitors to enable its operation. The figure below shows the amplifier circuit diagram:

|  |  |
| --- | --- |
|  |  |

**Figure 4.** Signal amplifier circuit.

Two amplifier stages were used in Circuit 2, so the circuit shown in the figure above was repeated. Each step was responsible for amplifying the voltages of a coil. One terminal of a coil was connected to Vi and the other terminal to the circuit earth. Vs was connected to the 12 V battery supply. The speaker RL shown connected in the circuit diagram above was not used in this design. The node connecting the capacitors C4 and C5 of the amplifier stage was connected in the rectification step.

This stage was composed of a TIL 111 CI, the node connecting the capacitors C4 and C5 was connected directly to the resistor terminal of 330R in the figure below:

|  |  |
| --- | --- |
|  |  |

**Figure 5.** Noise filter with CI TIL 111

This circuit receives the amplified voltage at port 1. This voltage lights an integrated LED in the circuit and thus generates a continuous voltage at port 4 of the IC. Likewise a repeat of the rectification circuit was incorporated in order to rectify and stabilize the amplified voltages of the two coils.

The figure below shows the layout of the circuit designed using the Proteus Ares software:

|  |  |
| --- | --- |
|  |  |

**Figure 6.** Layout of circuit 2 generated in Proteus Ares

The following figure shows the list of materials used to construct the circuit board

|  |  |
| --- | --- |
|  |  |

**Figure 7.** Component list

These components were of course soldered to the board.

The figures below show the design of the circuit board and the actual circuit board as constructed:

|  |  |
| --- | --- |
| (**a**) | (**b**) |

**Figure 8.** (a) Component layout; (b) Printed circuit board.

Circuit 3

The next step was the creation of Circuit 3. Circuit 3 was responsible for receiving information from the amplification stage. Using this data, it would then feed the motors with the necessary voltage to keep the robot on its predetermined course. Note that if the left motor turned less than the right, the robot would turn to the left and vice versa. If the coils were not aligned and equidistant from the wire, this circuit, coupled to the Arduino UNO, would receive and process the information from Circuit 2, and would then send the necessary voltage to the motors in order to control their rotation.

The driver module IBT\_2 was used in this circuit. This module is a power amplifier for controlling motors with voltages that range from 12 V to 36 V with a current of up to 48 A. This module amplified the voltage coming from ports 3 and 5 of the Arduino, and controlled the motors of the robot through the voltage delivered to the motor terminals. For more information, please consult the component data sheet.

The figure below shows the outline of the IBT\_2 connections:

|  |  |
| --- | --- |
|  |  |

**Figure 9.** Circuit 3 sketch.

The M + and M- inputs were then connected to the motor terminals.

|  |  |
| --- | --- |
|  |  |

**Figure 10.** Circuit 3 mounted on a protoboard.