# DEVELOPMENT OF ELECTRONIC EDGE FINDER 

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## Thesis submitted in partial fulfilment of the requirements for the award of the degree of Bachelor of Mechatronic Engineering

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## SUPERVISOR'S DECLARATION

I hereby declare that I have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of the degree of Bachelor of Mechatronic Engineering.

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I hereby declare that the work in this project is my own except for quotations and summaries which have been duly acknowledged. The project has not been accepted for any degree and is not concurently submitted for award of other degree.

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## Dedicated to my mom

Siti Fatimah binti Harun

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#### Abstract

EDGE FINDER is a tool used to accurately determine edges or markings and therefore the center of a workpiece or a previously machined feature during the set-up phase of a machining operation. The electronic circuit has been designed to develop the Electronic Edge Finder. The electronic circuits contains of two magnetic wire probes when connected between the vise and the spindle of the milling machine. The Electronic Edge Finder is connected directly to the tool and spindle on the milling without any modification to the machine. It is detect the changes of the electrical resistance of the machine when there are contact between the workpiece and the tool. It is then to use to setting up the workpiece zero point by referring to the light of the LED on the Electronic Edge Finder circuit. At the end of the project, the Electronic Edge Finder is developed and can be used to setup the tool and marked the zero point on the workpiece.


#### Abstract

ABSTRAK "EDGE FINDER" adalah alatan yang digunakan untuk menentukan bucu atau menandakan origin pada bahan kerja. Proses ini akan dilakukan semasa fasa persediaan sebelum menjalankan sebarang aktiviti yang melibatkan mesin. Litar elektronik telah dicipta untuk menghasilkan "ELECTRONIC EDGE FINDER". Litar elektronik ini mengandungi dua set wayar magnet yang menghubungkan gelendong dan ragum pada mesin. Wayar magnet ini dihubungkan secara terus tanpa perlu ada pengubahsuaian pada mesin. Litarini akan mengesan perubahan rintangan elektrik apabila alat pada gelendong mesin bergerak menghampiri bahan kerja pada ragum. Litar ini digunakan untuk menentukan origin padabahan kerja berdasarkan nyalaan LED pada litar elektronik. Akhirnya, "ELECTRONIC EDGE FINDER" dihasilkan dan digunakan untuk menandakan titik origin pada bahan kerja.


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## LIST OF ABBREVIATIONS

| EEF | Electronic Edge Finder |
| :--- | :--- |
| DTI | Dial Test Indicator |

## CHAPTER 1

## INTRODUCTION

### 1.1 OBJECTIVES

Edge finder is an important tool that used in machining process to ensure the center and the zero point of the workpiece. The operation is done before continue to the process of machining. In order to complete the project, there are few objectives that should be constructing. The objectives of this study are:
i. To design the electronic edge finder.
ii. To develop the edge finder.

### 1.2 PROJECT BACKGROUND

This project is all about the development of an Electronic Edge Finder. Edge finder is a tool used in the spindle of a machine such as a milling. The device is used to accurately determine edges or markings and therefore the center of a workpiece or a previously machined feature during the set-up phase of a machining operation.

In this project, the electronic edge finder is connected directly to the tool and spindle on the milling without any modification to the machine. The edge finder can detect when the tool comes in contact with the workpiece. It is detect the changes of the electrical resistance of the machine. It is detecting the differences between the low electrical resistance between all parts of the milling and the extremely low resistance at the point where the tools first contacts the workpiece. It will be known by alarm in terms of lighting and buzzing.

At the end of the project, the Electronic Edge Finder can be used to set the zero point and to mark the center of the workpiece base on the light of the LED that place in the electronic circuit.

### 1.3 PROJECT SCOPE

This project is about the development of electronic edge finder. The method that used to achieve the objective is by using electrical circuit that contains two probes. These two probes are connected to the tool and the workpiece respectively. In order to complete this project, precise scope of work and plan should be followed to achieve the objective. The scopes of study are:

1. Study on the application of the edge finder on milling.
2. Study the method of zero setting using edge finder.
3. Research on the development of the edge finder.
4. Design an edge finder for zero setting.

### 1.4 PROBLEMS STATEMENTS

Zero point setting is an important process in machining. The method that can be used for setting the zero margins on the workpiece can be done by using mechanical edge finder or electronic edge finder. In this project all about the electronic edge finder.

In order to machine metal, wood or plastic accurately in a manual mill, it is essential to accurately set zero point. The electronic edge finder can be used without changing the tool at the machine compared to other conventional method. These devices are easy to used for the machinist. On the other hands, by using this electronic edge finder, it will reduce the time needed to complete a process of machining. It is because, the machinist no need to change the tool. The zero point setting can be proceeding by using any tool either for the previous or next process.

## CHAPTER 2

## LITERATURE REVIEW

### 2.1 EDGE FINDER

Edge finder is a tool used in the spindle of a machine such as a milling (Fig 2.1). The device is used to accurately determine edges or markings and therefore the center of a workpiece or a previously machined feature during the set-up phase of a machining operation. A rotating tool, meaning the machine spindle must be turning for the tool to work.


Figure 2.1: Edge Finder

### 2.2 TOOL FOR ZERO POINT SETTING

Zero point setting on the workpiece can be done by using various method and tools. The methods are by using the Mechanical Edge Finder, Optical Edge Finder, Bump Method, Wiggler, Light-Cut Method, Dial Test Indicator (DTI), and also by Using Laser Edge Finder.

### 2.2.1 MECHANICAL EDGE FINDER

These methods are usually used to set zero point on the workpiece. The tools that used in this process are a spring loaded conical disc (Fig. 2.2). This disk has to spin to complete this operation. This mechanical edge finder utilizes a spring loaded conical disc that spins while free of the workpiece and then suddenly kicks or slips sideways when contact with the edge of the workpiece is obtained. The disc of this type of edge finder only slips a certain amount and the goes no further. As a result, the machinist can back up and try again without having to reset the contact by hand. Once the edge is found, the machinist moves the workpiece, generally by moving the mill table, over one-half the diameter of the edge finder to align the spindle axis with the plane of the workpiece edge. Some of these types of edge finder include a conically-shaped center finder having a pointed end that is utilized in the same manner as spring loaded conical disc [2].


Figure 2.2: Mechanical Edge Finder

### 2.2.1.1 The Process of Zero Point Setting By Using Mechanical Edge Finder.

The mechanical edge finder can be used for zero point setting. The edge finder is located in the collets on the spindle milling machine. The spindle is turned ON and the side finders are move slowly toward the workpiece. When the two pieces are exactly straight (Fig 2.3), tool are moved further and the tools are not straight line (Fig 2.4). The points are set as zero [3].


Figure 2.3: Edge finder inline


Figure 2.4: Edge Finder not inline

### 2.2.2 OPTICAL EDGE FINDER

The optical edge finder (Fig. 2.5) is advancement of Mechanical Edge Finder. There are few advantages that come with this device. The benefit is, by using this methods, it will save time to find positions, for milling machine, jig borers and other machine tools. The scope of application includes edge surface, inside and outside diameters and high efficiency. There is a safety spring puller, which will put a ball precisely back to the position when ball breaks away from ball seat [3].


Figure 2.5: Optical Edge Finder

### 2.2.2.1 The Process Of Zero Point Setting Using Optical Edge Finder

The optical edge finders are mounted into the spindle and its concentricity are checked (Fig. 2.6). The worktables of milling machine are moved to make the edges of workpiece touch the ball off the edge finder until the red lamp is alarm (Fig. 2.7). The dial reading of the table movement are marked, the table are moved backward a little. The edge finder is slightly re-touching the edge finder until the red lamps are alarmed once again. It is to make sure and to get the correct reading (Fig. 2.8). The reading of the dial is marked as zero and the tables are moved to the desired position (Fig. 2.9). The edge finders are taken off and remount the desired tooling for machining (Fig. 2.10).


Figure 2.6: Concentricity checked


Figure 2.7: The red lamp is alarm


Figure 2.8: Re-touch edge finder to get correct reading


Figure 2.9: Tables are moved to the desired position


Figure 2.10: Remount the desired tooling for machining

### 2.2.3 BUMP METHOD

This Bumb Method is mostly practices by the machinists to set zero point on the workpiece. It is about to locate the center or edge of a workpiece relative to a milling machine or other machine tool indirectly locate the reference mark. A common method is to find an edge of a workpiece is generally referred to as a contact or bump method. In this method, a simple piece of round stock is placed in the mill spindle and the work tool is hand cranked to gently but the edge of the workpiece against the round stock. To align the work machine with the edge of the workpiece, the machinist then raises the round stock above the workpiece and moves the workpiece over half the diameter of the round stock. The micrometer dial setting at this position is zeroed to correspond to the edge of the workpiece, thereby aligning the work tool (i.e., the spindle centerline) with the plane running through the edge of the workpiece [3]

Although the contact or bump method is quick and simple, it is well known that it is generally not that accurate due to the inherent problems associated with trying to recognize when the contact occurs and the elasticity of the materials involved. In addition, to the inherent accuracy problems, it is not that uncommon for machinists, particularly relatively inexperienced or hurried machinists, to forget to take into account the one-half of the diameter of the round stock used as the edge finder. Another problem known to be associated with this method of edge finding is that too much contact against the workpiece, which for certain metals is not that much contact, can dent or otherwise damage the workpiece [3].

### 2.2.4 WIGGLER

Another method for finding the edge of a workpiece utilizes a tool commonly known as a wiggler, which has been used by machinist for over a century. Most wiggler sets come with an edge finder component that has a generally mushroom-shaped disk contact at the end of the wiggle shank opposite that which fits into the collet, typically in a ball and socket type of arrangement. As with the contact method described above, the workpiece is moved towards the spinning edge finder until it gently touches the disk contact and steadies the wiggling. The workpiece is then slowly dialed further towards the edge finder until it is spinning true (i.e., no wiggle). At the point the edge finder starts to slip sideways from the drag of the spinning disk against the workpiece, the machinist has found the edge of the workpiece. As with the contact method, the machinist then raises the edge finder and dials in half of its diameter, typically 0.100 inches, to align the spindle centerline with the edge plane of the workpiece. Although the wiggler edge finder is generally considered to be very accurate for routine machine work and good enough for most high precision work, it is known to be frustrating to utilize due to the fact that it has to be reset for each edge contact [3].


Figure 2.11: Set of Wiggle

### 2.2.5 DIAL TEST INDICATOR (DTI)

The dial test indicators (Fig. 2.12) are used to set zero point on mills. By using dial test indicator, it will inform when the workpiece are precisely touched down on a surface. On the other hands, dial test indicator (DTI) are also used to measure runout. The dial test indicators are applicable to set zero point for the cylindrical workpiece. It will bring up to the side of a cylinder that can rotate; the dial test indicator is then zeroed. As the cylindrical is turned, the reading of maximum positive and maximum negative is detected [4].

The dial test indicators are actually measures angular displacement and not linear displacement. As the finger of dial test indicator are moves, its pivots around a central point. This rotation is geared to the pointer [4].


Figure 2.12: Dial Test Indicator

### 2.2.6 LIGHT- CUT METHOD

Light cut is one of the method that can be use to establish a point on the X or Y axis as zero. The most accurate that has been used is to make a light cut on the part stop with the end mill and set 0 (refer Fig. 2.13). This is the key idea in soft jaws. It is fine as long as all cuts are on that side of the end mill. If switch to the other side, error can creep in if don't know the exact diameter of the end mill. It is also not always practical to cut the stop. The width of that slot is exactly how wide that end mill will cut when mounted in this collet and spindle when cutting aluminum to this depth. Beyond these caveats, long cuts can suffer from variations in the ways. All that is left is to accurately measure this slot. Not all that easy to do with a caliper since the bottom of the slot is not perfectly square and the slot is rather shallow [5].


Figure 2.13: Light Cut Method

### 2.2.7 LASER EDGE FINDER

The laser edge finder (Fig. 2.14) is a new applications in a various situations in the metals, wood and plastic industries. In all cases the simplicity of visual operations and accuracy allow machine operators to quickly establish location points, edges, centers of materials, centers of hole, scribes lines, alignment of vises on mill table, centering of rotary tables and spin indexers. The laser edge finder can also be placed in lathe tailstock after off-set for taper cutting and to set lathe tool bit height. The unit also can be used to visually set the mill head angle [6].


Figure 2.14: Laser Edge Finder

### 2.3 MILLING MACHINE

A milling machine is a machine tools used to machine solid workpiece. Milling is the process of machining flat, curved, or irregular surfaces by feeding the workpiece against a rotating cutter containing a number of cutting edges. Milling machine removes metal with a revolving cutting tool called a milling cutter. By using milling machine, it can perform a vast number of operations, from simple operation to the complex operation. With various attachments, by using milling machines for boring, slotting, circular milling, dividing, and drilling; cutting keyways, racks, and gears; and fluting taps and reamers [7].

There are classed into two basics forms which are horizontals and verticals (Fig. 2.15). All this refers to the orientation of the main spindle. Milling machine have to move the workpiece radially against the rotating milling cutter to cuts on its side. Milling machines are basically classified as being horizontal or vertical to indicate the axis of the milling machine spindle. These machines are also classified as knee-type, ram-type, manufacturing or bed type, and planer-type milling machines [7].


Figure 2.15: Vertical and Horizontal Milling Machine

### 2.3.1 TYPES OF MILLING MACHINE

Milling machine has a various type of machine. In this chapter, there are two type of machine that will be discussed. There are the knee-type milling machine and ram-type milling machine.

### 2.3.1.1 KNEE-TYPE MILLING MACHINE

This type of machine is a one of the vertical milling machine. It is because this machine can be adjusted by its worktable. Knee-type milling machines are characterized by a vertical adjustable worktable resting on a saddle supported by a knee [8]. The spindle can be adjusted by vertical movement, and the table can be moved vertically, longitudinally, and transversely. We can control the movement of both the spindle and the table manually or by power. The knee is a massive casting that rides vertically on the milling machine column and can be clamped rigidly to the column in a position where the milling head and the milling machine spindle are properly adjusted vertically for operation [8].

## a. Floor-mounted Plain Horizontal Milling Machine

i. It is contains the drive motor and, gearing and a fixed-position horizontal milling machine spindle. An adjustable overhead arm, containing one or more arbor supports projects forward from the top of the column [8]. The arbor can be adjusted at the desire position. The arm and arbor supports are used to stabilize long arbors, upon which the milling cutters are fixed. This support will depend on the location of the milling cutter or cutters on the arbor [8].
ii. A heavy, vertical positioned screw beneath the knee is used for raising and lowering. The saddle rests upon the knee and supports the worktable. The saddle moves in and out on a dovetail to control the cross feed of the worktable.

## b. Bench-Type Plain Horizontal Milling Machine

i. The operation of this machine is a same as Floor-mounted Plain Milling Machine but in smaller size and it is mounted to the bench not to the floor. The spindle on this machine are fixed and in horizontal position. The worktable for this machine mostly can be adjusted manually because of the smaller size. The milling machine spindle is horizontal and fixed in position. An adjustable overhead arm and support are provided. The worktable is generally not power fed on this size machine [7].


Figure 2.16: Plain Horizontal Milling Machine

## c. Floor-Mounted Universal Horizontal Milling Machine

i. The differences between the plain and universal horizontal milling machine (Fig. 2.17) is about the adjustment of the worktable. On the other hand, the number of attachments and the accessories for special operations also differ. The universal horizontal milling machine has a worktable that can swivel on the saddle with respect to the axis of the milling machine spindle, permitting workpieces to be adjusted in relation to the milling cutter. The universal horizontal milling machine also differs from the plain horizontal milling machine in that it is of the ram type [9]. For example, the milling machine spindle is in a swivel cutter head
mounted on a ram at the top of the column. The ram can be moved in or out to provide different positions for milling operations [9].


Figure 2.17: Universal Horizontal Milling Machine

### 2.3.1.2 RAM-TYPE MILLING MACHINE

This type of machine can be known by the spindle that mounted on the column. The ram-type milling machine is characterized by a spindle mounted to a movable housing on the column, permitting positioning the milling cutter forward or rearward in a horizontal plane. Two widely used ram-type milling machines are the floor-mounted universal milling machine and the swivel cutter head ram-type milling machine [10].

## a. Universal Ram-Type Milling Machine

This type of machine has the same operations as Universal Horizontal milling machine. The difference being as its name implies, the spindle is mounted on a ram or movable housing [10].
b. Swivel Cutter Head Ram-Type Milling Machine (Fig. 2.18)

The spindle of this machine is attached at the ram. The cutter head can be swivel from a vertical to horizontal spindle position or vice versa. The cutter head can be swiveled from a vertical to a horizontal spindle position, or can be fixed at any desired angular position between the vertical and horizontal. The saddle and knee are driven for vertical and crossfeed adjustment. The worktable can be either hand driven or power driven at the operator's choice [10].


Figure 2.18: Swivel Cutter Head Ram-Type Milling Machine

## CHAPTER 3

## METHODOLOGY

### 3.0 INTRODUCTION

Methodology is an organized flow that functioned to guide a study to reach the desired objective. The progress and the flow of this study is all recorded and can be tracked in this chapter. In this project, the electronic circuit is the main component to ensure that the objective of this project is achieved. This topic will be discussed further through this chapter.

### 3.1 METHODOLOGY FLOW CHART



Figure 3.1: Methodology Flow Chart

The methodology for this project starts with literature review on related topic on research, written journals, and books that has been established earlier. From the literature review, problem statement is generated and objective been defined. Problem statement and objective has been mentioned earlier in Chapter 1. Then, as this project used an electronic circuit as a method to develop the Electronic Edge Finder, a design of the circuit is generated.

To develop the Electronic Edge Finder, the electronic circuit should be design. This electronic circuit is attached with two magnetic wire probes. Magnet has been incorporated into the ends of the probes so an electrical connection is made by simply placing them on clean, steel surfaces. There are two probes which is has two magnetic clips respectively. The circuits use commonly available integrated circuit (LM 324), one transistor, two diodes, two LEDs, 15 resistors including a trim pot and 6 capacitors. It is powered by a single 9 V battery. The list of the components involves in the project is shown in Table 3.1.

Based on the design of the electronic circuit, the circuit should be tested on the milling machine to ensure that the circuit are function correctly. If there is problem with the result that supposedly comes out, the circuit should be redesign. This step is repeated until the result is satisfied.

| BIL | COMPONENTS NAME | VALUE | QUANTITY |
| :---: | :---: | :---: | :---: |
| 1. | Resistors | $220 \Omega$ | 1 |
| 2. | Resistors | $1 \mathrm{~K} \Omega$ | 2 |
| 3. | Resistors | $5.1 \mathrm{~K} \Omega$ | 2 |
| 4. | Resistors | $1.8 \mathrm{~K} \Omega$ | 1 |
| 5. | Resistors | $2.2 \mathrm{~K} \Omega$ | 1 |
| 6. | Resistors | Ten turn $10 \mathrm{~K} \Omega$ trim pot | 1 |
| 7. | Resistors | $220 \mathrm{~K} \Omega$ | 4 |
| 8. | Resistors | $1 \mathrm{M} \Omega$ | 1 |
| 9. | Resistors | $2.2 \mathrm{M} \Omega$ | 2 |
| 10. | Capacitor | 0.01 uf ceramic | 3 |
| 11. | Capacitor | 0.1 uf ceramic | 2 |
| 12. | Capacitor | 100 uf 16 V nonpolarized electolytic | 1 |
| 13. | Led (white) | - | 2 |
| 14. | General purpose signal diode | - | 2 |
| 15. | Transistor | 2N4402 | 1 |
| 16. | Integrated circuit | LM 324 | 1 |
| 17. | Clips | - | 4 |
| 18. | Battery | 9V | 1 |
| 19. | Box | - | 1 |
| 20. | PCB board | - | 1 |

Table 3.1: List of Components

### 3.2 SYSTEM BLOCK DIAGRAM

It is started with the test current generator (Fig. 3.2). It applies 20 mA to the resistance between cutter and spindle. It also signals the automatic power control circuit. As long as the test current flows, power is applied to the rest of the circuit. The cutter to spindle resistance can be as small as 10 milliohms so the voltage generated by the 20 mA test current is only 200 micro volts.

The drop in resistance at touchdown is on the order of 0.16 milliohms which generates a change in voltage of -3.2 micro volts. It is this tiny drop in voltage that the circuit is able to detect. The circuit has two phases. In the first phase it is constantly calibrating to the non-touchdown resistance. In the second phase it is detecting the sudden drop in resistance.

During calibration, the voltage generated across the cutter to spindle resistance is amplified by a factor of -122 by the voltage amplifier. It then passes through the touchdown amplifier which multiplies it by -1 . The voltage is then applied to the automatic threshold generator which computes and stores the proper threshold that must be crossed in order to signal touchdown.

During the second phase, the circuit reacts to only the sudden drop in resistance. It causes a tiny drop in the voltage generated across the cutter to spindle resistance. This voltage drop is amplified by the voltage amplifier just like during the first phase. But then it is further amplified by -100 in the touchdown amplifier. The signal is then sent to the touchdown detector where the threshold has already been set. The detector sends a signal to the touchdown LED driver which in turn lights the touchdown LED.


Figure 3.2: Block Diagram

### 3.3 THE MAGNETIC WIRE PROBES

The magnetic probes are used in this electronic edge finder. It is used to connect the conductivity between the vice and the spindle of the milling machine. In order to build the magnetic wire probes, the required component is the magnet and the female spade clip (Fig3.3).

The first step is, soldering the wire to the female spade clip. Then, crimp the wire to secure the wire. The magnet is placed in the clips so that the two clips in a pair repel at their edges. This will keep them apart. After securing the first pair, place the second pair of magnets so they repel at the edge but also attract the other set of probes. The bottom clip is HC 1 and its mate is SP 1 . On the top probe, the bottom clip is SP2 and the top is HC2. This puts the high current clips on the outside of the connection and the sensing clips on the inside.


Figure 3.3: The Spade Clip and the Magnet

### 3.4 DESIGN THE ELECTRONIC CIRCUIT

The design of the electronic circuit is drawn by using Pspice software. This is to make the process of design the circuit on a board become easier because it can be as guidelines. The design of the circuit desired in this project is shown in the Figure 3.4.


Figure 3.4: Electronic Circuit Diagram

The electronic circuit for Electronic Edge Finder is then built on the breadboard. This is easier to test on the breadboard first, before finalize the circuit. It is because; in this board any modification can be made in order to get the functional circuit. The entire component is place on the board with addition of some jumper to connect the electronic component (Fig 3.5).


Figure 3.5: Circuit Design on the Breadboard.

Then, this circuit should be tested on a milling machine to get the initial result (Fig 3.6). This is also to determine whether this circuit can be used for Electronic Edge Finder. So, if any modification that should be makes for the circuit, it can be done directly. The tested usually should be for many times to ensure that the electronic circuit are function correctly as requested.


Figure 3.6: The Circuit Test on the Milling Machine

### 3.5 CIRCUIT ETCHING

The design for the Electronic Edge Finder circuit etching should be proceed after the initial result has been achieved. The design for PCB board can be done by using Express PCB software. The design of the circuit should be printed on the paper by using laser jet printer. This is to make sure that all the connection of the component is covered by the carbon on the PCB layout (Fig.3.7).


Figure 3.7: PCB layout

The PCB layout paper is drenched with sunflower-seed oil or any types of oil. The oil is used to make the white part of the layout paper transparent for light. The protective plastic layer is removed - peeled back - from the photosensitive PCB. The toner side of the greased layout is placed on the copper of the PCB. Captured airbubbles are gently pressed away from underneath the layout. The PCB with the layout is now covered with an appropriate sized windowpane and placed on a piece of plain polished tile or marble. The tile or marble absorbs the heat coming from the UV bulb or the sun, which is significant. Three to four minutes 300 W bulb UV exposure from a distance of $30-40 \mathrm{~cm}$ will do the photo process or almost one minute if used the natural UV.

The PCB is developed with a $1 \%$ solution of sodium hydroxide $(\mathrm{NaOH})$. The solvent make by adding 10 gram of sodium hydroxide pellets to 1 litre of water and mix it until everything is dissolved. The brush is used to speed up the developing and clean the PCB during this process if the PCB is still greasy due to the applied sunflower-seed oil. The developing process takes about 1 minute. The traces should become clear and the exposed photosensitive layer has dissolved

The developed PCB is etched with a $220 \mathrm{~g} / \mathrm{l}$ solution of ammonium peroxydisulfate $\left(\mathrm{NH}_{4}\right)_{2} \mathrm{~S}_{2} \mathrm{O}_{8}$ a.k.a. ammonium persulfate, 220 gram added to 1 liter of water and mix it until everything is dissolved (Fig 3.8). When the ammonium peroxydisulfate is dissolved it is a clear liquid. After an etching procedure it gradually becomes blue and deeper blue - the chemical reaction creates dissolved copper sulfate $\mathrm{CuSO}_{4}$. Compared to other etching chemicals like hydrated iron (III) chloride $\mathrm{FeCl}_{3} \cdot 6 \mathrm{H}_{2} \mathrm{O}$ a.k.a. ferric chloride or the combination of hydrochloric acid HCL and hydrogen peroxide $\mathrm{H}_{2} \mathrm{O}_{2}$, using ammonium peroxydisulfate is a clean and safe method.


Figure 3.8: PCB Board Etching in Solution of Ammonium Peroxydisulfate

### 3.6 COMPONENT ARRANGEMENT

Component arrangement should be proceed after finish with etching process, now the hole on the PCB board should be make in order to replace the electronic component. The hole can be done by using the hand drill. Then, the component is located on the PCB board (Fig 3.9). Then, the component should be soldered to make sure the circuit will flow correctly. Finally, the Electronic Edge Finder circuit are tested on the milling machine to get the final result. Then, the box for the circuit should be made to place the circuit nicely.


Figure 3.9: Component Placed on PCB Board

## CHAPTER 4

## RESULT AND DISCUSSION

### 4.0 INTRODUCTION

In this chapter, it will be discuss about the result of the Electronic Edge Finder. After all the procedures is followed the analysis about the circuit can be proceed. In this project, the result of the circuit is mostly can be ensure by the light of the two LED that is placed in the circuit.

### 4.1 TRIM POT ADJUSTMENT PROCEDURE

Trim pot adjustment procedure is needed to maximize the sensitivity to touchdown while minimizing sensitivity to electrical noise (Fig 4.1). The magnetic probe wire should connect to the vise and the spindle on the milling machine. This is to ensure that the circuit is connected, so the Power On LED will lighted up. On the starting, these LED will flick. It is needed to adjust the trim pot until the Power On LED stop flickering.

The first set of probe is attached on the spindle while the other set is on the vise of the milling machine. The workpiece is placed in the vise, and then start the trial touchdown. If the touchdown LED flickers, slightly adjust the trim pot until the LED remain dark.


Figure 4.1: Trim Pot for adjustment

### 4.2 THE MAGNETIC PROBE WIRE

The magnetic probe wire is attached on the electronic circuit of this Electronic Edge Finder to connect the conductivity between the vise and the spindle of the milling machine (Fig 4.2).


Magnetic probe on the spindle

Magnetic probe on the vise

Figure 4.2: The Probe on the Milling Machine

### 4.3 TEST CURRENT GENERATOR

$I_{s}$ flows through a pair of High Current probes marked as HC 1 and HC2. The resistances of these probe wires and the contact resistance of the clips causes a voltage drop. This drop is tiny compared to the battery voltage but could be huge compared to the voltage being sensed.

The test current, Ix (Fig 4.3), is set by $\boldsymbol{R}_{2}$ :

$$
\begin{aligned}
& I_{x}=\frac{V \text { battery-Veb1-VD1 }}{R 2} \quad \text { Eqn } 4.1 \\
& I_{x}=\frac{9 V-0,75 V}{220 \Omega} \\
& I_{x}=0.0375 \mathrm{~A}
\end{aligned}
$$



Figure 4.3: Test Current Generator Circuit Diagram

In order to solve this problem, a second set of probes is used to only sense the voltage across $R_{X}$. Almost no current across in this signal probe (SP) leads so no appreciable voltage is generated in the wires or probes. If $R_{X}$ is above 35 ohms , diode D2 turns on to limit the voltage to less than 0.7 volts.

SP2 defines ground for the circuit. When this probe is disconnected, $\boldsymbol{R}_{\mathrm{E}}$ proves a path to the negative battery terminal. That prevents the ground node from floating which can make it susceptible to electrostatic discharge damage.
$I_{X}$ does a few other things besides generating the input voltage for the voltage amplifier. As it flows through $R_{1}$, it turns on the power control circuit. This current also flows through $D_{1}$ which lights it to indicate power is on. The voltage drop across $D_{1}$ is used to define the negative terminal of the battery to be at around 3 volts below ground.

### 4.4 POWER CONTROL

When the wire probes has detected the conductivity between the vise and the spindle on the milling machine, the Power On LED will lighted up (Fig 4.4).


Figure 4.4: Power On LED lighted up

The current, $I_{x}$ are flow through $R_{1}$ (Fig 4.5) causes the voltage of emitter - base of transistor 2N 4401 rise. When the circuit turned on, the voltage across emitter- base is around 0.75 v . the voltage across the $Q_{1}$ is constant. The current flow through $R_{1}$ and rest flow out of base $Q_{1}$. Therefore,

$$
\begin{align*}
I_{x} & =\frac{0.75 \mathrm{~V}}{1 k}  \tag{Eqn 4.2}\\
& =0.75 \mathrm{~mA}
\end{align*}
$$



Figure 4.5: Power Control Circuit Diagram

The collector current on $Q_{1}$ is far less than 20 mA so $\boldsymbol{Q}_{1}$ is driven deep into saturation. The quad op amp integrated circuit is then essentially tied to $V_{c c}$, the positive terminal of the battery. When $\mathrm{HC1}$ is disconnected from the lathe or mill, $I x$ drops to zero, $Q_{1}$ turns off, and power is removed from the circuit.

### 4.5 CUTTER TO SPINDLE RESISTANCE

The Cutter to Spindle Resistance can be measure through the magnetic wire probes. The two sets of the magnetic probes wire are HC 1 pair with SP 1 and HC 2 pair with SP2 respectively. The Cutter to Spindle Resistance represented by $R_{\mathcal{R}}$ (Fig 4.6).

$$
V_{x}=R_{x} x I_{x}
$$

Eqn 4.3


Figure 4.6: Cutter to Spindle Resistance Circuit Diagram

These 10 milliohms is shorted by the touchdown resistance which can be as large as 0.6 ohms. This causes the 10 milliohms to drop to $\frac{R_{X} \mathrm{X} R_{t d}}{R_{x}+R_{t d}}$ at touchdown. That is a drop of 164 micro ohms. It calls this change $\Delta R_{R}$. Equation 4.4 still holds for changes in resistance.

$$
\begin{aligned}
\Delta V_{x} & =\Delta R_{x} \times I_{x} \\
\Delta V_{x x} & =0.49 \Omega \times 0.01 \mathrm{~A} \\
& =4.9 \mathrm{mV}
\end{aligned}
$$

$$
\text { Eqn } 4.4
$$

### 4.6 VOLTAGE AMPLIFIER

The voltage generated across $R_{X}$ is carried by probes SP1 and SP2 to the voltage amplifier (Fig 4.7).


Figure 4.7: Voltage Amplifier Circuit Diagram

The output voltage is at pin 1 and is called $V_{1}$ :

$$
V_{1}=G_{A} \times 4.9 \mathrm{mV} \quad \text { Eqn }
$$

Where $G_{A}=-\frac{R T}{R 4}$

$$
\begin{gathered}
V_{1}=-\frac{220 \mathrm{R}}{1 . \mathrm{R}} \times 4.9 \mathrm{mV} \\
=-122(4.9 \mathrm{mV}) \\
=0.5978 \mathrm{~V}
\end{gathered}
$$

Capacitor $C_{1}$ in conjunction with $R_{7}$ causes the gain of this amplifier to drop as the signal frequency rises. It needs to pass some high frequencies in order to see touchdown but at the same time no need to see the electrical noise present in the room.

The frequency equals,

$$
\frac{1}{2 x \pi x R 7 x C 1}=\frac{1}{2 x \Pi x 220 K x 0.01 \mu f}=72 \mathrm{~Hz}
$$

Time constant,

$$
\begin{aligned}
R_{7} \times C_{1} & =220 \mathrm{~K} \times 0.01 \mu \mathrm{f} \\
& =2.2 \text { milliseconds }
\end{aligned}
$$

This is the same time constant as the touchdown amplifier but 50 times smaller the next largest time constant. This fact will come in handy when analyzing other functional blocks.

### 4.7 TOUCHDOWN AMPLIFIER

This amplifier has two different gains. During the compensation phase, $C_{2}$ charges up to $V_{1}$ and then becomes an open circuit (Fig 4.8). $C_{3}$ charges up to $V_{7}$ and also becomes an open circuit. We are left with $R_{\S}, R_{10}$, and $R_{11}$.


Figure 4.8: Touchdown Amplifier Circuit Diagram

This amplifier has two different gains. During the compensation phase, $C_{2}$ charges up to $V_{1}$ and then becomes an open circuit. $C_{3}$ charges up to $V_{7}$ and also becomes an open circuit. We are left with $R_{9}, R_{10}$, and $R_{11}$ :

$$
\text { Compensation phase: } \quad \begin{aligned}
V_{7} & =-\frac{R 11}{R 9+R 10} \times 0.5978 \\
V_{7} & =-\frac{220 \mathrm{~K}}{220 K+2.2 \mathrm{~K}} \times 0.5908 \\
& =0.5849 \mathrm{~V}
\end{aligned}
$$

The time constant related to $\mathcal{C}_{2}$,

$$
\begin{aligned}
& =R_{10} \times C_{2} \\
& =2.2 \mathrm{k} \Omega \times 100 \mu \mathrm{~F} \\
& =220 \text { milliseconds. }
\end{aligned}
$$

Touchdown phase:

$$
\begin{aligned}
V_{7}=G_{B} & \times V_{1} \\
\text { Where } G_{A} & =-\frac{R 11}{R 10} \\
V_{7} & =-\frac{220 \mathrm{~K}}{2.2 \mathrm{~K}} \times V_{1} \\
& =-100(4.9 \mathrm{mV}) \\
& =-0.49 \mathrm{~V}
\end{aligned}
$$

This gain drops to $-\frac{100}{\sqrt{2}}=-70.7$ at a frequency of 72 Hz due to $C_{3}$ and $R_{11}$.

### 4.8 AUTOMATIC THRESHOLD GENERATOR

During the compensation phase, the capacitor, $C_{4}$ (Fig 4.9), charge up to a given DC voltage and can then be ignored. We will be in the compensation phase up to the moment of touchdown. In other words, up to $t=0$. The voltage $V_{10}(0-)$ comes from a voltage divider made up of $R_{12}$ and $R_{13}$.


Figure 4.9: Automatic Threshold Generator Circuit Diagram

$$
\text { Compensation phase: } \begin{aligned}
& V_{10}(0)
\end{aligned}=\frac{R_{43}}{R_{12}+R_{13}} \times V_{7}(0) ~ 子 \begin{aligned}
V_{10}(0) & =\frac{2.2 M}{2.2 M+2.2 M} \times V_{7}(0) \\
V_{10}(0) & =0.5 \times V_{7}(0) \\
V_{9}(0) & =V_{7}(0)
\end{aligned}
$$

So as long as $V_{7}(0)$ is positive, $V_{10}(0)-V_{9}(0)$ will be negative and $V_{9}(0)$ will sit near the op amp's negative rail, -3 V .

During $V_{10}(0+)$ both start to fall but at different rates. The time constant of $V_{7}$ (t) is on the order of a few milli seconds. The time constant of $C_{4}$ with the parallel combination of $R_{12}$ and $R_{13}$. is 110 milli seconds. So I will again ignore the effects of the capacitors in the voltage and touchdown amplifiers which slow down $V_{7}(\mathrm{t}) . V_{10}$ immediately after touchdown essentially does not move.

### 4.9 TOUCHDOWN DETECTOR

The $V_{0}$ high at about $\mathrm{t}=0+$ (Fig 4.10). It will go back low after various capacitors charge to the new values. It defines $t_{1}$ as the minimum time that $V_{\mathrm{s}}$ drops back to -3 V . Op amp C has a guaranteed minimum output current of 20 mA . When $V_{6}$ jumps from -3 V up towards +6 V , it will turn on $D_{3}$ and start to charge $\mathcal{C}_{6}$. The voltage across $C_{6}$. started at 0 because $R_{14}$. discharged it. If there is time, it will charge up to about $6 \mathrm{~V}-0.65 \mathrm{~V}=5.35 \mathrm{~V}$. Once it crosses 0 V with respect to ground, op amp D which acts as a comparator, will change state. $\boldsymbol{V}_{14}$ will swing from -3 V to +6 V .
To be fully charged up to +5.35 V , it need:

$$
\begin{equation*}
5.35=-3+\frac{20 m A x+1}{0.1 \mu F} \tag{Eqn 4.5}
\end{equation*}
$$



Figure 4.10: Touchdown Detector Circuit Diagram

Which gives $t_{1}=42$ micro seconds. So if $V_{8}$ stays high for at least 42 microseconds, $C_{5}$. will be fully charged. This 42 micro seconds is much smaller than the 110 millisecond time constant affecting the input to op amp C. So it can be sure that there will be plenty of time for $C_{6}$. to be fully charged.

V14 swung up to +6 V when $\mathrm{C}_{6}$. charged up past 0 V . That was shortly after $\mathrm{t}=0$. $V_{8}$ must stay at +6 V for at least 42 micro seconds but could stay up longer, $V_{8}$ drops back down to -3 V at t 2 . With $V_{8}$ no longer holding up $V_{12}, C_{6}$ starts to discharge.

C6 is discharged by $R_{14}$, so:

$$
\begin{aligned}
& V_{12}(t)=\left\{\Delta V_{12}\right\}\left\{1-e^{\left.\frac{-(t-t z\}}{\tau \varepsilon}\right\}}\right\}+V 12\left(0^{-}\right) \\
& \text {Eqn } 4.6 \\
& \text { Where, } \quad \tau 6=R_{14} \times C_{6} \\
& =(1 M) x(0.1 \mu f) \\
& =0.1 \text { second }
\end{aligned}
$$

### 4.10 TOUCHDOWN LED

The output of op amp D is at -3 V , there is no voltage across the touchdown LED or its current limiting resistor, $R_{15}$. But during the time from $t_{2}$ to $t_{3}, V_{14}$ is at 6 V so the voltage across $R_{15}$ is at $6 \mathrm{~V}-\mathrm{VD} 4-(-3)$. $D_{4}$ drops approximately 3 V so R 15 has about 6 V across it. Since it is 1 K , this means that the current through it is about 6 mA . This current also flows through $D_{4}$ which is a Super Bright LED. The 0.1 second flash of light from $D_{4}$ is easy to see (Fig 4.11).


Figure 4.11: Touchdown LED Circuit Diagram

The Electronic Edge Finder tested on the milling machine, the oscilloscope is attached to the circuit through the $\boldsymbol{R}_{\mathbf{1 5}}$. Refer to the graph on the Figure 4.12, the top trace represents the voltage at the top of $R_{15}$. While the bottom trace represent the voltage out of the touchdown amplifier.


Figure 4.12: Graph on Oscilloscope

In order to set the zero point on the workpiece, the tool on the spindle machine should move towards the workpiece on the vise. If there is no movement to the workpiece, its mean that there is no changes of the electronic resistance detected. When the voltage that flow through the $R_{15}$ is LOW, the Touchdown LED is Off (Fig. 4.13).


Figure 4.13: Voltage Through $\boldsymbol{R}_{\mathbf{1 5}}$ is LOW

If there is movement to the workpiece, its mean that there is changes of the electronic resistance detected by the circuit. When the voltage that flow through the $R_{15}$ is HIGH, the Touchdown LED is ON (Fig. 4.14).


Figure 4.14: Voltage Through $\boldsymbol{R}_{\mathbf{1 5}}$ is HIGH

## CHAPTER 5

## CONCLUSION AND RECOMMENDATION

### 5.0 INTRODUCTION

This chapter will summarize the results from the experiment done in Chapter 4. In this project, since the objective of the project is to develop the Electronic Edge Finder, the functional of the electronic circuit will be discussed.

### 5.1 CONCLUSION

The Electronic Edge Finder can be used without changing the tool at the machine compared to other conventional methods. The Electronic Edge Finder is developed in this project by using the electronic circuit. The Electronic Edge Finder will detect the changes of the resistance between the vise and the spindle of the machine when it used to determine the zero point of the workpiece.

The Power On LED will light when the electronic circuit in close circuit. Then, when the circuit detect the changes of the electronic resistance, the Touchdown LED will light. The center and the zero point can be ensuring refer to the light of the LED. This can be used to set-up the workpiece. The Electronic Edge Finder will benefits the user by reduce the set-up time. The Electronic Edge Finder can be used without changing the tool on the spindle of the machine either for previous or next process of machining

### 5.2 RECOMMENDATION

An Electronic Edge Finder can be improved in the future. The Electronic Edge Finder should be more sensitive to the changes of the resistance between the vise and the spindle of the milling machine. It should detect the small changes of resistance without damage the workpiece during the set-up process because Electronic Edge Finder cannot measure the force while it touches the workpiece. It is can be more precise to use the Electronic Edge Finder if the device can measure the forces that produce from the movement of the tool to the workpiece. It is to avoid from the damaged of the workpiece.

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## APPENDICES

1. Gantt Chart for Final Year Project 1
2. Gantt Chart for Final Year Project 2
3. Datasheet of LM 324
4. Datasheet of 2 N 4001
5. Circuit Diagram
