THIN FILM SEMICONDUCTOR CHARACTERIZATION DEVICE

By

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FINAL REPORT

Submitted to the Electrical & Electronics Engineering Programme
in Partial Fulfillment of the Requirements
for the Degree
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(Electrical & Electronics Engineering)

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CERTIFICATION OF APPROVAL

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Approved:

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CHAPTER 1
INTRODUCTION

This is a follow up prototyping project, novel temperature control unit for the thin film semiconductor experiment chamber. The report will mainly discuss on the solution for the unstable temperature fluctuation in the temperature control and the chamber modification. The coming project milestone include validating the previous student's on-off controller, PID control system theory review, checking the feasibility implementing the PID control algorithm into the PIC controller, the pro and cons of the control algorithm and modify the chamber to couple with the current design change. The report will also discuss on the suitable material used for the insulation leg of the elevated heater vault.

1.1 Background Study

The purpose of this project is to create a working prototype of thin film semiconductor experimental chamber with computer interface temperature control. Before going into the computer interface development stage, some fixing has to be done due to the unstable temperature. From the result obtain from the previous student, the novel temperature control unit will overshoot around 10 °C each time the heater turn on. From the source code, the heater will turn on for 1second after the temperature drop below the desire value. The mechanism is simple, the microcontroller act as the main switch, at the mean time, it also refresh the input from the keypad continuously and display the output temperature to the LCD. When the sensor detect the temperature lower than the desire value, it will trigger on the output for 1second. Then, the relay will turn on the heater at the same amount of time as well. As shown in Fig1.

1.2 Problem Statement

The temperature fluctuation of the industrial standard is $\pm 2^0$ C. However, the current temperature controller will produce a constant overshoot of 10 °C. The existing controller algorithm will be examine closely and consider other available controller too. The most possible controller to be considered is the PID controller as it is cheap and simple.

Besides, an air tight chamber is essential to fulfill the HSE requirement and ensure the accuracy of the test. The chamber will fit the current heater position and sensor configuration.

1.2.1 Problem identification

ON/OFF temperature control is the simplest and least expensive form of control available. The output signal from a controller is either FULL ON or FULL OFF depending on the direction of the deviation from a set point.[1] It is just like a bimetal thermostat, disconnecting the heater to the power source when the desire temperature achieved. The on off controller is cheap for application like refrigerator and air conditional. However, the on off controller is not suitable for the sensitive device like CPU, or the novel temperature control unit itself because it need a stable and persist temperature to conduct an experiment. The following is the characteristic of the on off temperature controller.

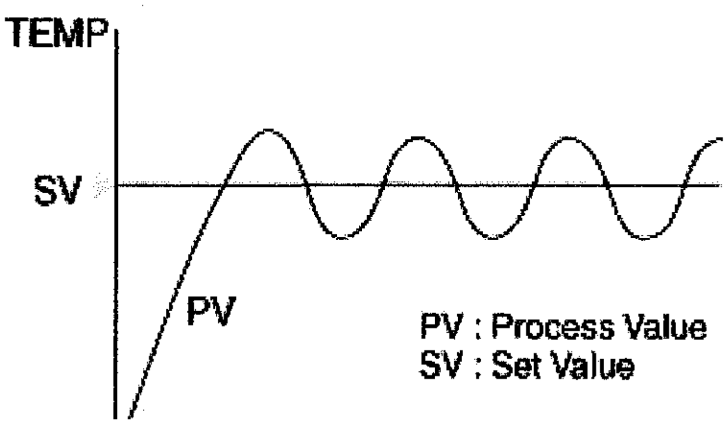


Figure 2 On/Off controller Respond [1]

The graph show the similarity to the result obtained by the previous student of the typical on off controller. Note that the difference is the result obtained by the previous student Fig. 3 doesn't have any negative part temperature momentum and the actual temperature always remain above the set value.

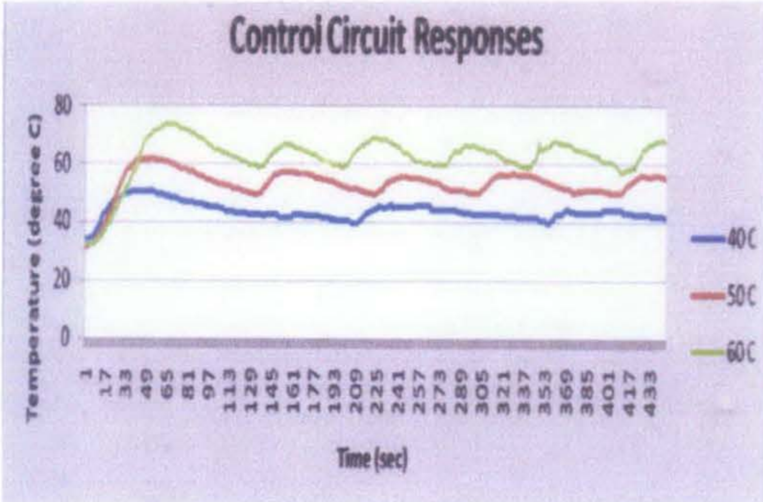


Figure 3 Output of previous student

ON/OFF temperature control action takes place if any deviation occurs from set point. This action responds quickly but is sensitive to input noise which causes chattering (ON/OFF switching at short intervals). Therefore, in actual use, ON/OFF temperature control action has some hysteresis which is named dead band or control sensitivity. [1]

From Fig.3, the on respond of the temperature control unit is almost instantaneous while the excessive heat generated by the heater for 1 second takes some time to for the environment to cool it down to the desire temperature. The 10 °C of hysteresis is the dead band of the system. Note that the higher the temperature, the faster the respond is. This is because the cooling effect is more significant due to the relative temperature with the environment.

To achieve the stabilized output over some transient, the Proportional feedback action is consider. Proportional negative-feedback systems are based on the difference between the required set point and measured value of the controlled variable. This difference is called the offset. Power is applied in direct proportion to the current measured offset, in the correct sense so as to tend to reduce the offset (and so avoid positive feedback). The amount of corrective action that is applied for a given offset is set by the gain or sensitivity of the control system. [2] Proper adjustment of the proportional band will result in smooth control. However, it is seldom that the actual temperature stabilizes exactly on the set point, and it usually becomes stable with some deviation called offset Fig.4. [1]

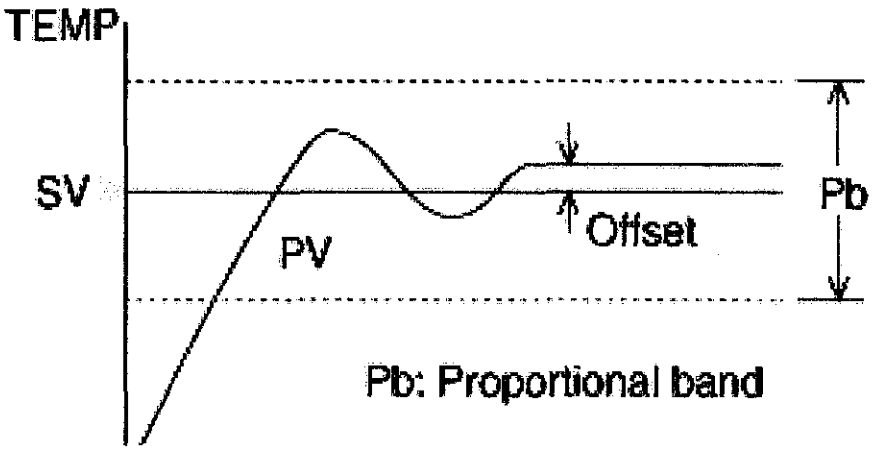


Figure 4 Proportional Respond [1]

Beside, the current chamber configuration is built up by a upper lid with a gas inlet, the body and a base with 3 gas outlet and 2 wire duct. 3 gas outlet is excessive and need 3 additional tube to collect it. If the gas is release to the atmosphere, that would be a hazard. Beside, the wire duct shall reduce into one. Extra wire duct raise the probability of the gas leakage and spoil the esthetical aspect of the chamber. Embedding the heater directly in base will also cause the base absorb large amount of heat from the heater and cause the entire chamber becoming very hot.

1.2.2 Significant of the Project

The on-off controller will cause an unstable oscillation of temperature trough out the entire time of operation. This will cause the experiment gone inaccurate and faulty.

Proportional controller is good at stabilizing the temperature over a period of time but it has some offset that make the end measured deviate from the desire value. This will reduce the accuracy of output temperature. The user may not obtain the desire temperature.

The 3 hole gas outlet is excessive and may require more duct to exhaust it. If the duct is not properly seal, this will result a HSE concern as the gas may hazardous. By reducing the exhaust duct into one hole, the exhaust gas can easily transfer to the filter. The extra wire duct may contribute to the hazard mentioned above. Beside, the embedded heater in the base may cause the entire body become very hot during the operating session. It will also reduce the efficiency of heating the thin film since the heating element have to heat up the body also. The base which is exposed to the environment may cause the heat loss increase. Therefore, there is a loss of energy. This will cause the entire chamber become very hot and become hazardous to the user. The embedded heater will also increase the temperature momentum and cause the overshoot become higher and the settling time increase.

1.2.3 Objective

a. Stabilize the temperature using certain control algorithm
b. Some review on control algorithms
c. Chamber modification and improvement
    i. Findings of insulation material for the elevated heater vault

1.3 Feasibility of the Project

The project consists of design and fabricates a stable temperature controller using PIC microcontroller. Since the PIC microcontroller is able to perform PWM, it is possible to implement a control algorithm into the PIC by programming it. PWM will convert the require intensity needed by the system into the duration for the heater to turn on. The modulated signal will represent the output of the algorithm. This is the major improvement to be made in this FYPI apart from the on-off controller.

CHAPTER 2
LITERATURE REVIEW

2.1 PID controller

To accurately control process temperature without extensive operator involvement, a temperature control system relies upon a controller, which accepts a temperature sensor such as a thermocouple or RTD as input. It compares the actual temperature to the desired control temperature, or setpoint, and provides an output to a control element. The controller is one part of the entire control system. [4] An on-off controller is the simplest form of temperature control device. The output from the device is either on or off, with no middle state. An on-off controller will switch the output only when the temperature crosses the setpoint. For heating control, the output is on when the temperature is below the setpoint, and off above setpoint. Since the temperature crosses the setpoint to change the output state, the process temperature will be cycling continually, going from below setpoint to above, and back below. [4] In cases where this cycling occurs rapidly, an on-off differential, or "hysteresis," is added to the controller operations. This differential requires that the temperature drop below the setpoint by a certain amount before the output will turn on again.

Proportional controls are designed to eliminate the cycling associated with on-off control. A proportional controller decreases the average power supplied to the heater as the temperature approaches setpoint. This has the effect of slowing down the heater so that it will not overshoot the setpoint, but will approach the setpoint and maintain a stable temperature. This proportioning action can be accomplished by turning the output on and off for short time intervals. This "time proportioning" varies the ratio of "on" time to "off" time to control the temperature. The proportioning action occurs within a "proportional band" around the setpoint temperature. Outside this band, the controller functions as an on-off unit, with the output either fully on (below the band) or fully off (above the band). However, within the band, the output is turned on and off in the ratio of the measurement difference from the setpoint. At the setpoint (the midpoint of the proportional band), the output on:off ratio is 1:1; that is, the on-time and off-time are equal. if the temperature is further from the setpoint, the on- and off-times vary in proportion to the temperature difference. If the temperature is below setpoint, the output will be on longer; if the temperature is too high, the output will be off longer. [4]

Consider the following proportional control model,

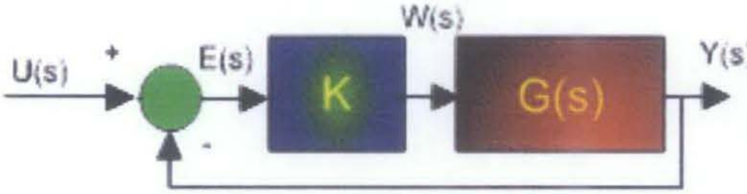


Figure 5 Proportional controller block diagram[5]

Where U(s) refer to input desire temperature, E(s) refer to Error, coefficient K refer to proportional gain, W(s) refer to control effort, G(s) refer to controller gain and Y(s) refer to Output. The purpose is to see the effect of proportional control at the output.

The output is given by

$$Y(s)=W(s)\times G(s) \tag{2-1}$$

and

$$W(s)=K\times E(s) \tag{2-2}$$

Note that the error = Input - Measured Output

$$E(s)= U(s)-K_s\times Y(s) \tag{2-3}$$

K_s refer to sensor gain. While in this case of model, we assume the sensor gain is unity.

Therefore,

$$Y(s)= G(s) \times K \times E(s)$$

$$Y(s)= G(s) \times K \times [\, U(s)-K_s \times Y(s)] \tag{2-4}$$

Solving for the output,

$$Y(s) = G(s) \times K \times U(s)/[1 + G(s) \times K_s \times K\,] \tag{2-5}$$

Where the error is

$$E(s)= U(s)/[1 + G(s) \times K_s \times K\,] \tag{2-6}$$

The error expression shows how much the output deviates from the input.

However, the proportional controller has several drawbacks although it can achieve a steady state. The fact is the error is impossible to achieve zero because zero error means to have zero output too. Therefore, the proportional controller has a little deviation from the desire input during the steady state. It is called steady state error. Note that the transient respond and the steady state error has close relation ship with the proportional gain. The higher the gain, the smaller the steady state error, but the larger the percent overshoot. On the other hand, reducing gain to reduce overshoot increased the steady state error. If dynamic compensators are used, compensating networks can be designed that will allow us to meet transient and steady state error specification simultaneously. [6] To cope with the steady state error, integral action is needed.

$$G_c(s) = K_1 + \frac{K_2}{s} = \frac{K_1\left(s + \frac{K_2}{K_1}\right)}{s}$$ (9.:

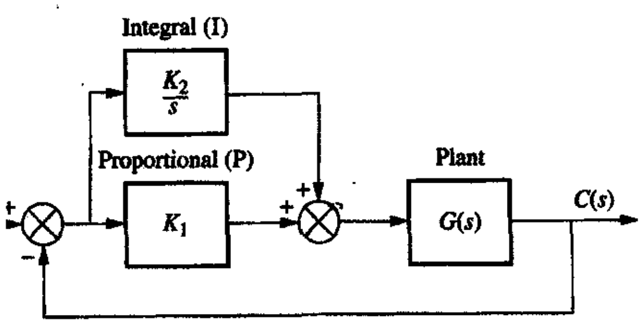


Figure 6 PI controller Block Diagram [6]

Steady state error can be improved by placing an open loop pole at the origin, because this increases the system type by one. [6] By inversing Laplace eqn. (2-6), the steady state error is

$$e(\infty)= \lim_{s\to 0}\frac{sU(s)}{1+G(s)} \qquad (2\text{-}7)$$

Let say the input is step input, U(s)=1/s

$$e_{step}(\infty)=\lim_{s\to 0}\frac{s(1/s)}{1+G(s)}=\frac{1}{1+\lim\limits_{s\to 0}G(s)} \qquad (2\text{-}8)$$

The equation show that it will result some steady state error unless

$$\lim_{s\to 0}G(s)=\infty \qquad (2\text{-}10)$$

Therefore, we introduce a ideal integral into the system by multiplying G(s) with 1/s, the equation become

$$e_{step}(\infty)=\lim_{s\to 0}\frac{s(1/s)}{1+G(s)/s}=\frac{1}{1+\lim\limits_{s\to 0}G(s)/s} \qquad (2\text{-}11)$$

Where if G(s) doesn't have any derivative action in it,

$$\lim_{s\to 0}G(s)/s=\infty \qquad (2\text{-}12)$$

therefore

$$e_{step}(\infty)=\frac{1}{1+\lim_{s\to 0} G(s)/s}=\frac{1}{1+\infty}=0 \tag{2-13}$$

To see how to improve the steady state error without affecting the transient response, look at Fig.7.

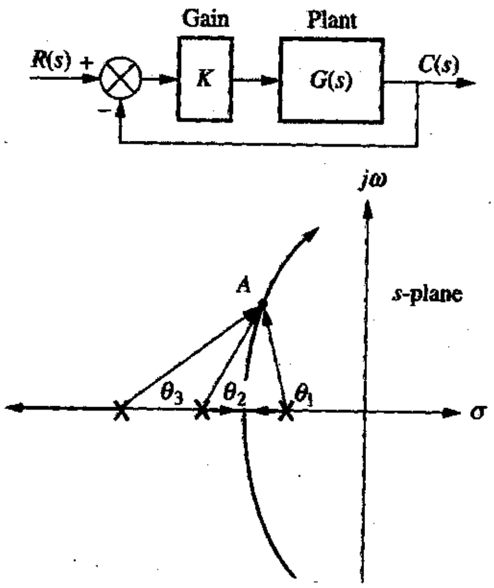


Figure 7 Proportional controller without compensation [6]

Here the system operating with a desirable transient response generated by the closed loop poles at A. If a pole is added at the origin to increase the system type, the angular contribution of the open loop poles at point A is no longer 180 degree, and the root locus no longer goes through point A, as shown in Fig.8

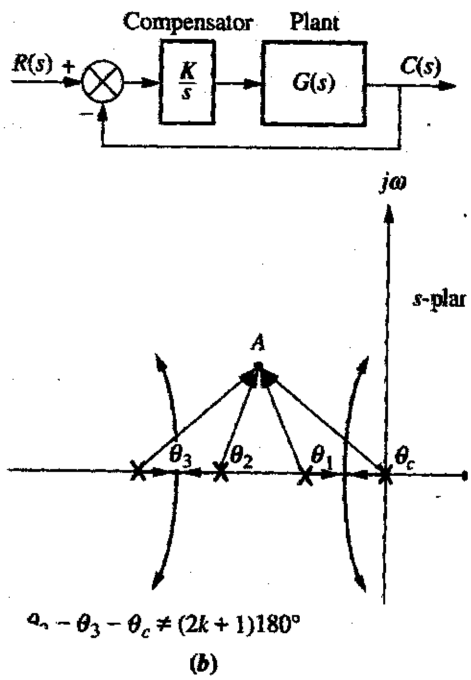


Figure 8 PI compensated system[6]

To solve the Problem, a zero is added close to the pole at the origin, as shown in Fig. 9 Now the angular contribution of the compensator zero and compensator pole cancel out, Point A is still on the root locus, and the system type has been increased. Furthermore, the required gain at the at the dominant pole is about the same as before compensation, since the ratio of lengths from the compensator pole and the compensator zero is approximately unity. Thus, the steady state error have been improved without appreciably affecting thee transient response. A compensator with a pole at the origin and a zero close to the pole is called an ideal integral compensator.[6]

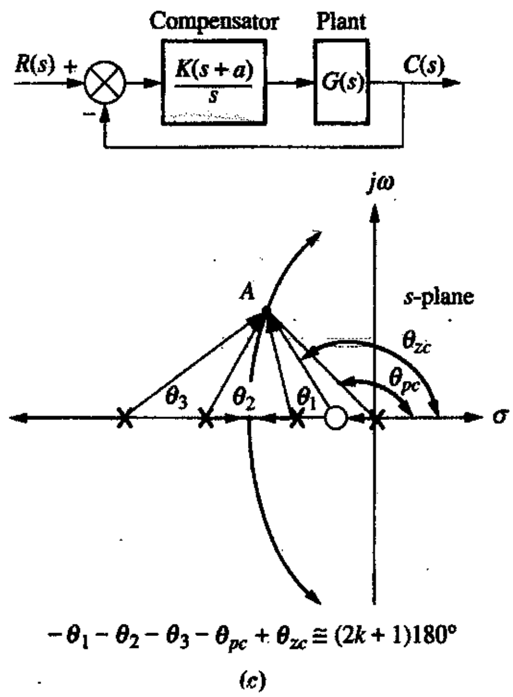


Figure 9 PI compensation with zero[6]

The following picture show the ideal integral compensated system and the uncompensated system.

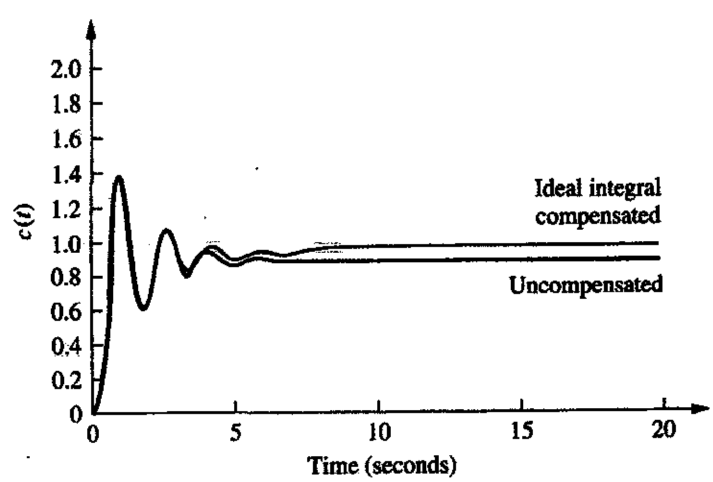


Figure 10 Comparison between PI and P controller[6]

In order to make the temperature achieve the steady state faster, ideal derivative compensation can be used. Adding a zero to the forward path will speed up the original system.

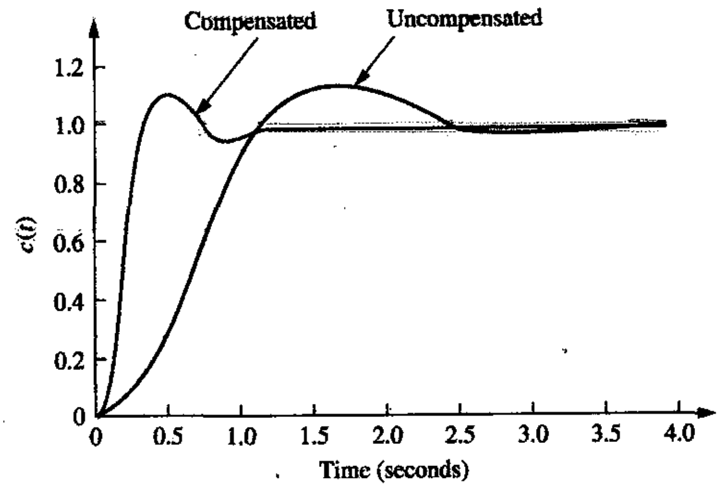


Figure 11 Comparison of P and PD controller[6]

By combining the characteristic of the 3 types of controller, the PID controller is introduce. Where the block diagram is shown.

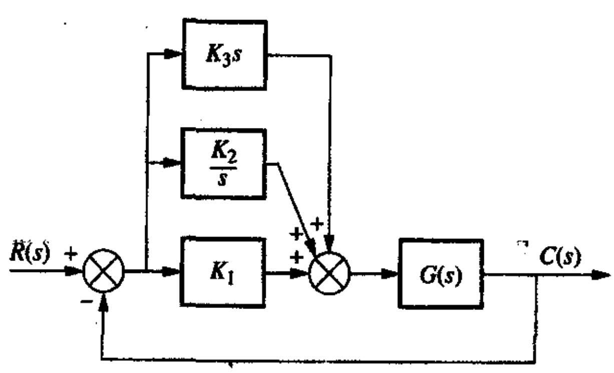


Figure 12 PID control [6]

This controller combines proportional control with two additional adjustments, which helps the unit automatically compensate for changes in the system. These adjustments, integral and derivative, are expressed in time-based units; they are also referred to by their reciprocals, RESET and RATE, respectively. The proportional, integral and derivative terms must be individually adjusted or "tuned" to a particular system using trial and error. It provides the most accurate and stable control of the three controller types, and is best used in systems which have a relatively small mass, those which react quickly to changes in the energy added to the process. [6]

PID controller is still widely used in industrial systems despite the significant developments of recent years in control theory and technology, because they perform well for a wide class of processes. Also, they give robust performance for a wide range of operating condition. Furthermore, they are easy to implement using analogue or digital hardware.[7] In digital hardware like PIC microcontroller, the implementation method is rather easy. The output of the system may undergo PWM before connecting to the relay and the heater. The power needed by the thin film is basically controlled by the duration of the heater being in the on or off state.

2.2 4 point probe resistivity measurement

A four point probe is a simple apparatus for measuring the resistivity of semiconductor samples. By passing a current through two outer probes and measuring the voltage through the inner probes allows the measurement of the substrate resistivity.

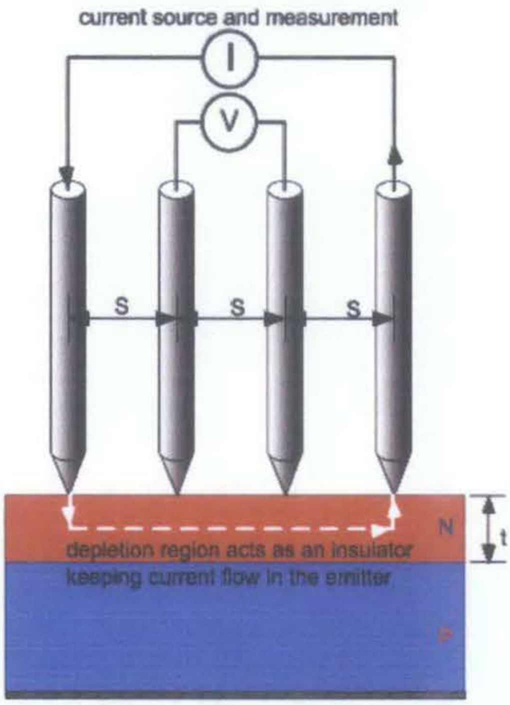


Figure 13 Use of a four point probe to measure the sheet resistivity of a thin film

Using the voltage and current readings from the probe:

$$\rho_{\square}\left(\frac{\Omega}{\square}\right) = \frac{\pi}{ln\,(2)}\frac{V}{I} \tag{2-14}$$

Where:

$$\frac{\pi}{ln2} = 4.53 \tag{2-15}$$

For high resistivity samples the current is reduced so as not to have an excessively larger voltage at the contacts. It is recommended that voltage on the inner probes be less than 100 mV/mm. Low resistivity samples are usually much easier to measure as the contacts to the silicon are ohmic. For very low resistivity you will have to increase the current to 45.3 mA and set the voltmeter to a lower scale.

The van der Pauw Method is a commonly used technique to measure the sheet resistance of a material. The Van der Pauw method is often used to measure the Hall effect, which characterises a sample of semiconductor material and can be successfully completed with a current source, voltmeter, and a magnet. [21]

From the measurements made, the following properties of the material can be calculated:

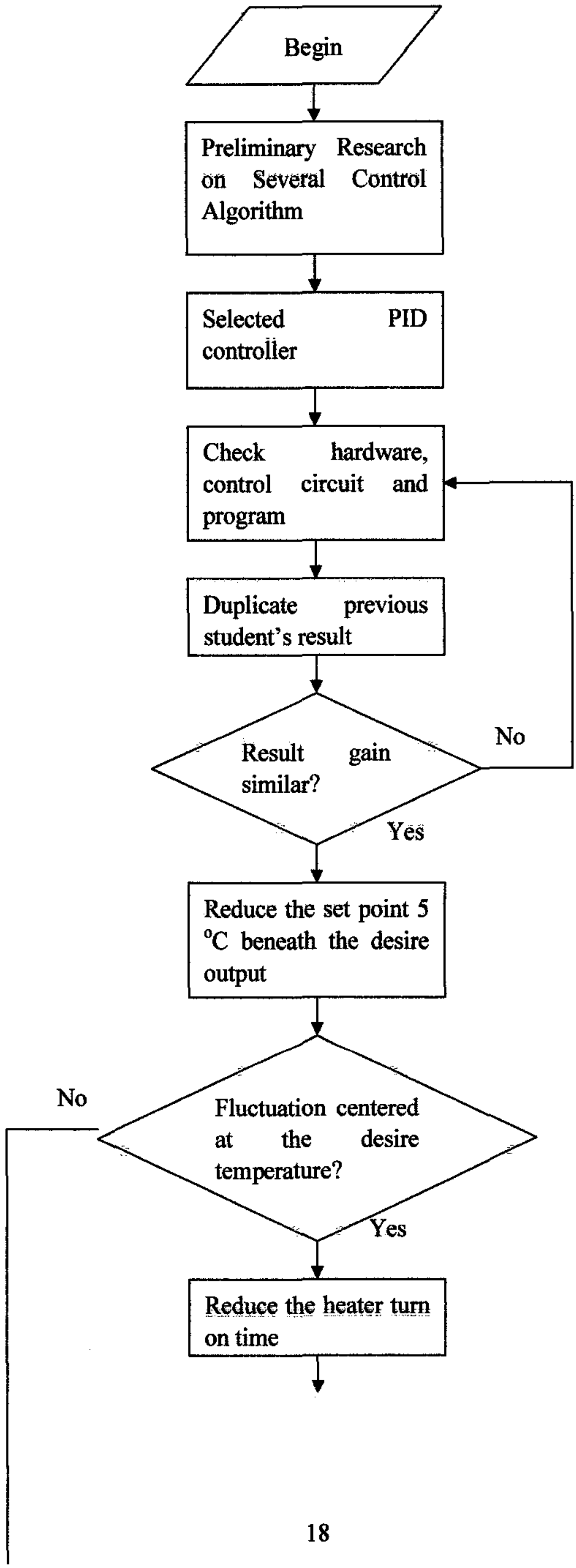
1. The sheet resistance, from which the resistivity can be inferred for a sample of a given thickness.
2. The doping type (i.e. if it is a P-type or N-type) material.
3. The sheet carrier density of the majority carrier (the number of majority carriers per unit area). From this, the density of the semiconductor, often known as the doping level, can be found for a sample with a given thickness.
4. The mobility of the majority carrier. [21]

CHAPTER 3
METHODOLOGY

3.1 Research Methodology and Project Activities

3.1.1 Controller Design

The research methodology including testing existing control algorithm and PID control algorithm in the novel temperature control unit. At first, the existing circuit will be verify and the functionality of the circuit part and component is tested. The PIC controller will be programmed again based on the previous students source code and the PIC controller manual. Before the controller will be programmed, the source code will run on the PIC 16f877 simulator and MPLab simulator. Once the circuit is done, the result of the previous student will be replicate and the research will be based on changing the algorithm inside the microcontroller to steady the output temperature. The 1^{st} and 2^{nd} experiment will still based on on-off controller.


Begin
Preliminary Research on Several Control Algorithm
Selected PID controller
Check hardware, control circuit and program
Duplicate previous student's result
Result gain similar?
No
Yes
Reduce the set point 5 °C beneath the desire output
Fluctuation centered at the desire temperature?
No
Yes
Reduce the heater turn on time

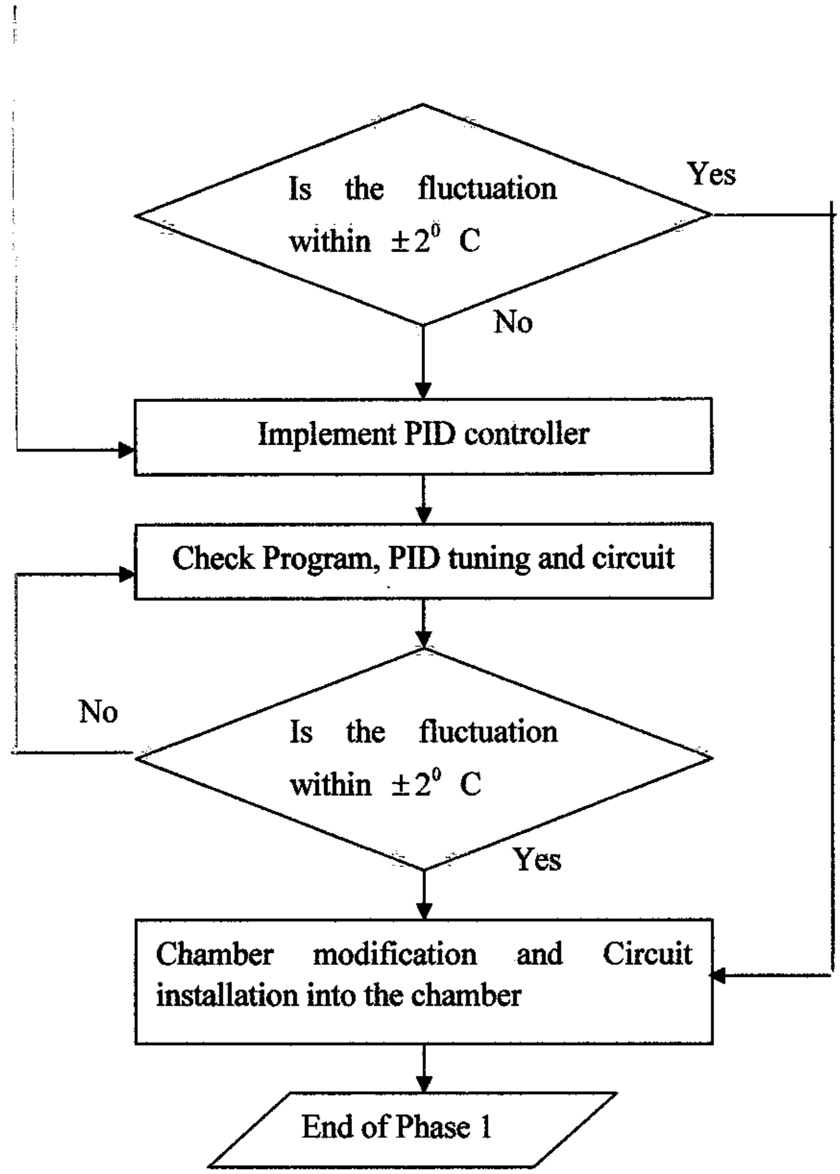


Figure 14 Methodology Flow

Proposing 1st experiment.- Reducing the set point about 5 °C lower than the desire temperature. Since the temperature momentum of the previous experiment is positive, the set point can be moved to the median of the error so that the error deviation is reduce. By moving the set point to the median of the error, the expected output will be similar to Fig. 2. Therefore, we have a deviation of $\pm 5^0$ C instead of 10 °C. Furthermore, the average temperature will almost similar to the set point.

Proposing 2nd experiment- Reducing the on time of the heater. The purpose is to check whether the effect will reduce the temperature momentum since the enery receive by the thin film is reduce. The turn on/off frequency will increase, shorten the time interval of on/off hence reducing the overshoot. If the temperature fluctuation reduce to $\pm 2^0$ C, the on-off controller will be retained. The following is the flow chart of the ON/OFF controller

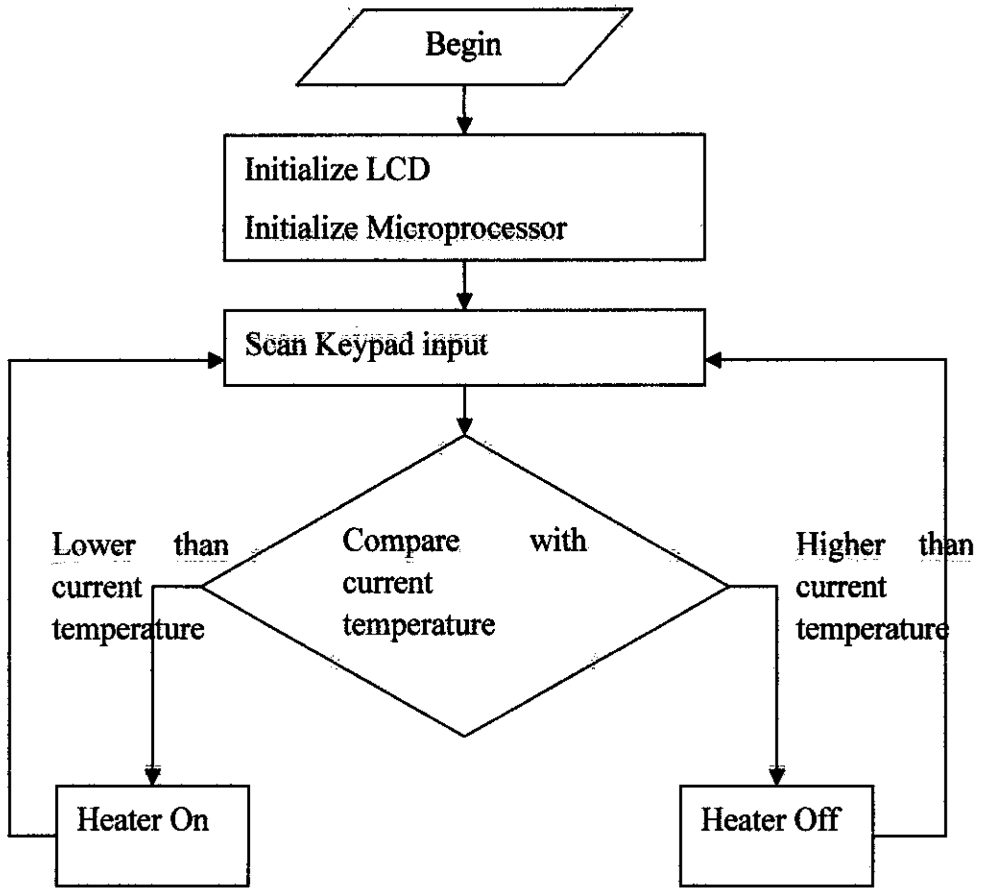


Figure 15 Flow chart of On/Off controller algorithm

Proposing 3rd experiment – PID controller implementation. If the experiments stated above fails the industrial standard, PID controller will be implemented into the PIC because it is reliable and accurate. The source code of the algorithm is in the appendix.

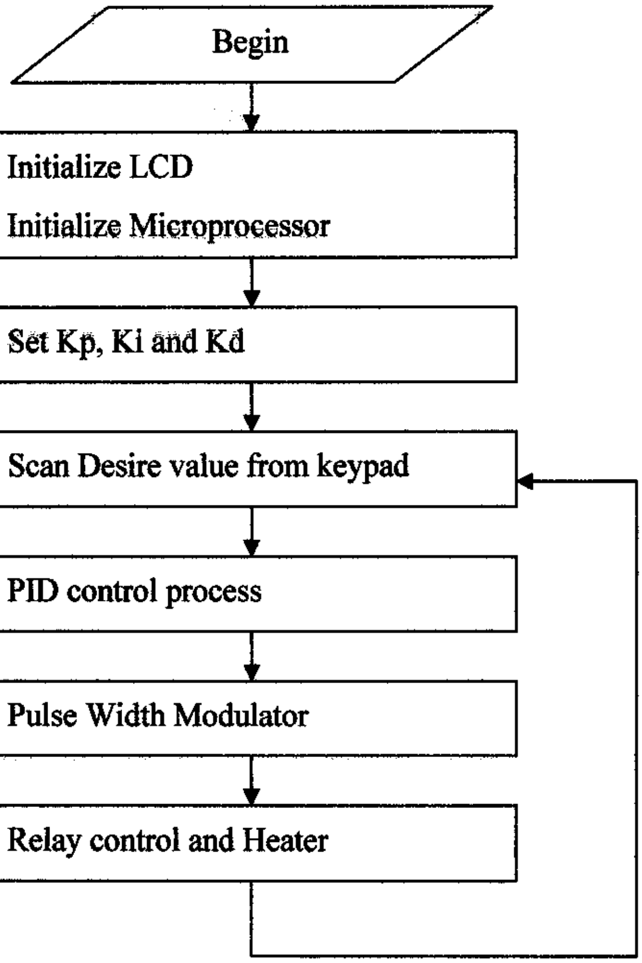


Figure 16 Flow chart of PID controller algorithm

DAC output is input modulation data of the PWM circuit and is required to determine the amount of heat generated by the heater.

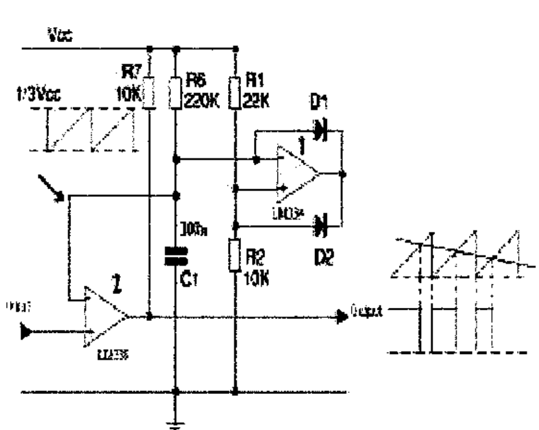


Figure 17 Pulse Width Modulation circuit

Charges and discharges of C1 creates a sawtooth signal. The 2nd voltage comparator LM339 is used to compare sawtooth and input signals. While amplitude of input signal is greater than the sawtooth's amplitude, the comparator output produces +VCC . [18]

Utilization of Yokogawa YS170 as a PID controller and RTD sensor to perform temperature control.

Figure 18 Yokogawa YS170

This controller could do the PID temperature control far more precise and accurate than the PIC microcontroller does. The PIC microcontroller could create problem such as relay threshold, where the relay could only function around 10 hertz while the PWM signal send out by the microcontroller may require more. Solution can be made by replacing the relay with power MOFSET or power switch with firing angle. But not as good as the Yokogawa YS170 due to the delay. The function of this PID controller is available in the appendix. Moreover, Difficult to program the algorithm into the PIC with user varying set point, PB, Ti and Td as the current PIC is already compensating the LCD, keypad, A/D conversion and comparison algorithm

Foxboro temperature transmitters combine microprocessor-based technology with advanced packaging. Resulting a high reliability, maximum flexibility, and exceptional intelligence sensor.

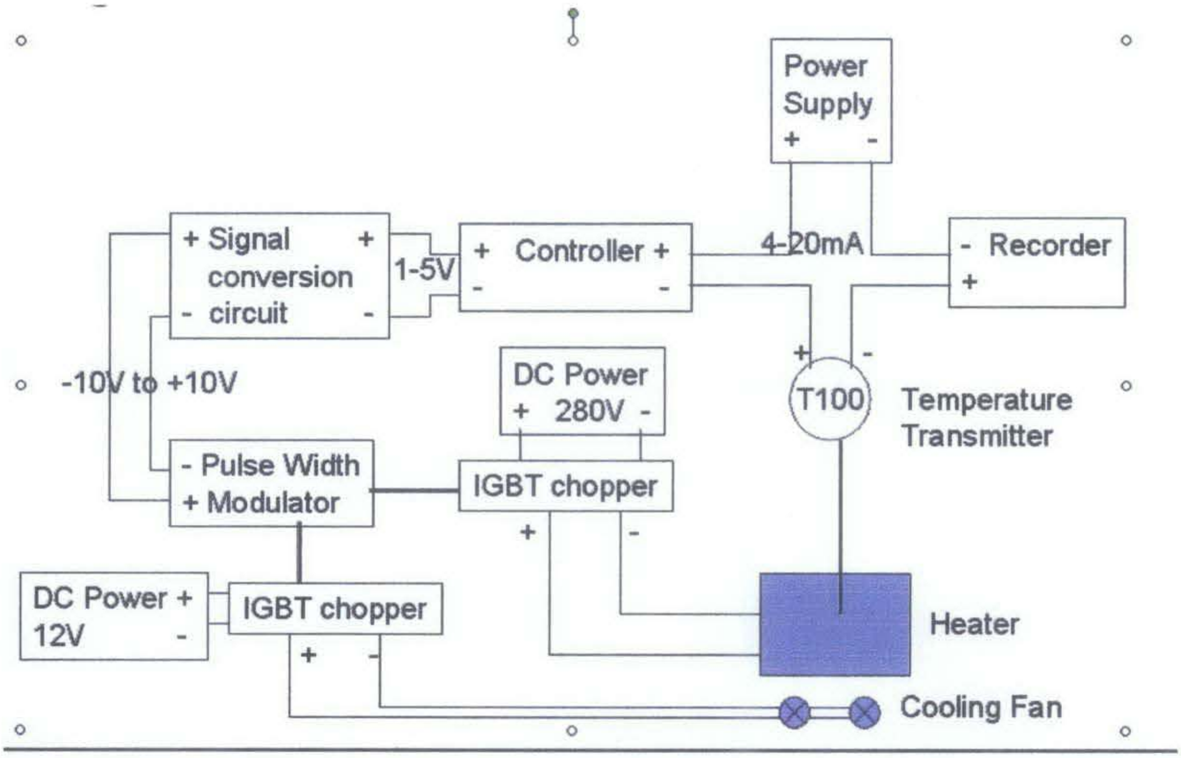


Figure 21 Connection

The temperature transmitter will sense the temperature of the heater and send it to the controller in the signal form of 4-20mA, direct acting. The recorder will record the current temperature, the set point and the MV(manipulated variable). After going thru PID control, the controller send the output signal MV in the form of 1-5V. However, the signal readable by the labvolt equipment is only -10 to 10V. So, a signal conversion circuit has to manually built to convert the signal to -10 to 10V. The signal conversion circuit is simply built by op-amp, with a clipping input voltage of 1V. The circuit is built from 2 set of op-amp amplifier, one is inverting amplifier to create a –10V and another one is non-inverting amplifier to create a 10V output.

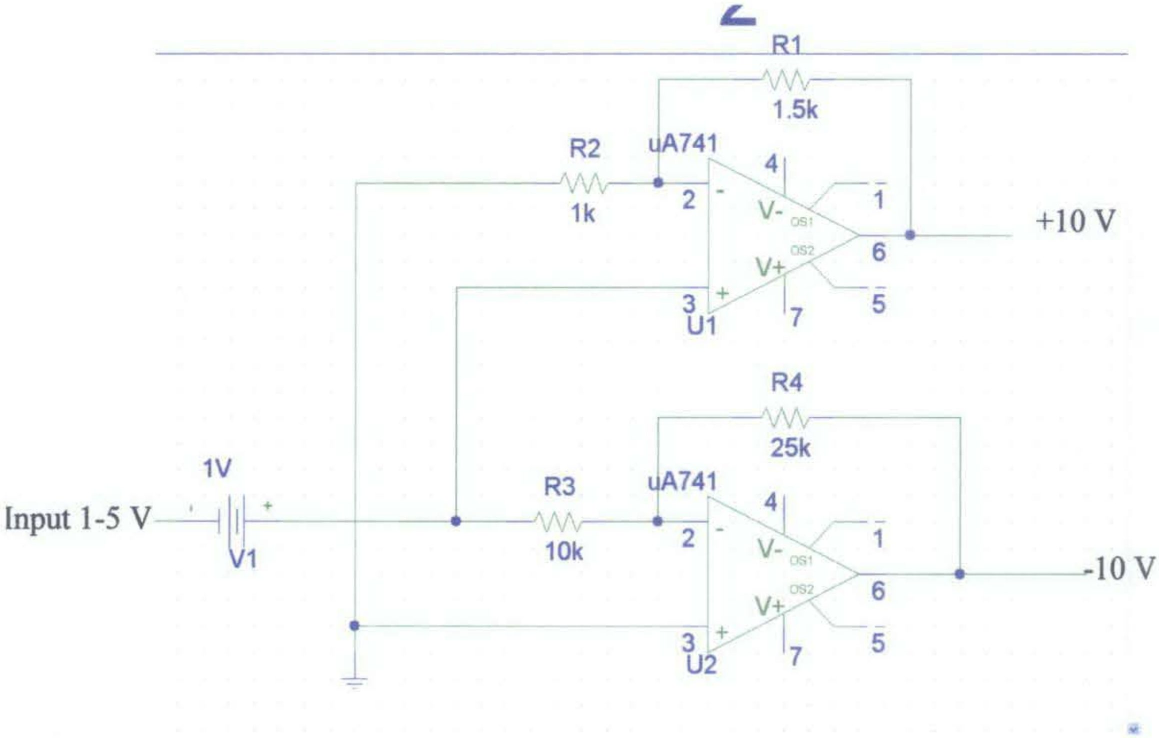


Figure 22 Op-amp for signal conversion

Notice that the 1-5V signal is clipped to 0-4 volt. Upper op-amp converting 0-4volt to 0to10V while lower op amp convert 4volt to 0to -10V.

Then, the PWM will determine the duration of the heater ON time by sending signal to IGBT chopper. The power diode will clip the DC power to the heater and hence, the amount of power sent to the heater can be controlled. Similar way applied to the fan, the difference is just the DC power supplied is smaller. Therefore, the fan speed will follow the % MV.

3.1.2 Chamber Design

In the mean time, the base of the chamber will be modify. Prior task include Autocad drawing and Mazak fabrication will be reproduced. The following is the picture of current of the chamber.

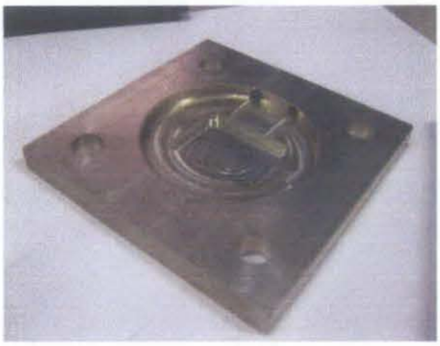


Figure 23 Original Chamber Base

The draft of the new chamber base would mainly based on HSE reason and effectiveness of the heat conservation. As shown in Fig 14.

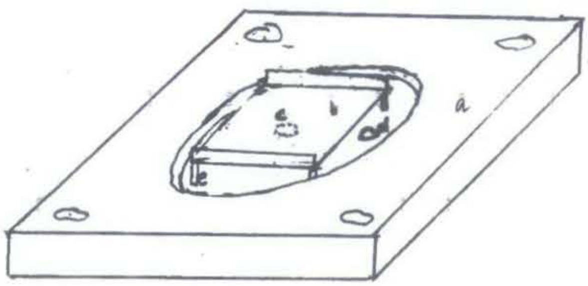


Figure 24 Proposed New Chamber base

The heater is elevated by four insulator (e). The heater sit at the designed aluminium plate (b). This may reduce the necessary heat to rise the chamber temperature. The temperature respond would be faster and effective. The gas outlet is place beneath the heater, (C), which allow the gas efficiently bath the test subject and reduce the risk of gas leakage. A hole is made for cable (d).

Proposing 4^{th}: chamber modification. The four elevated insulator Fig. 14(e) will use the ceramic fiber as the proposed insulation material. It is a cheap and common insulator used widely in industrial section. The reason of using ceramic fiber is because it is Low thermal conductivity, low heat storage, stability at high temperatures, excellent resistance to thermal shock, chemical attack, water and oil damage, reduced refractory heat-up and cool-down time, light weight for ease of handling, cutting, drilling, sawing and machining, excellent acoustic insulation.[15]
Properties and characteristics: Continuous use limit: up to 2300°F; melting point: 3200°F; thermal conductivity: 1.53°F per BTU-in/hr/ft2 at 1800° F ; density: 16 PCF (pounds per cubic foot); color: white [15]

Utilizing a wet forming manufacturing process, the material combine a blend of alumina-silica ceramic fibers with both organic and inorganic binders to improve handling strength and ensure material integrity at high service temperatures. The ceramic fiber available in various form and shape that may fit the usage of the elevated stand. For, example, YESO 1260 may provide an appropriate solution for the chamber. The following is the samples of the ceramic fiber.

Figure 25 YESO ceramic fiber products

The following implementation as shown:

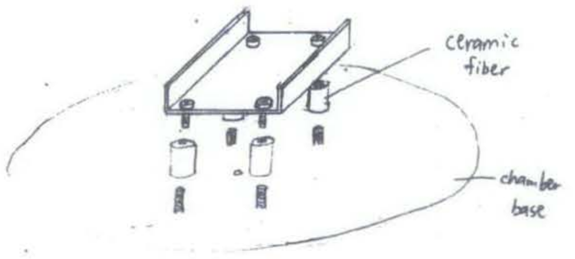


Figure 26 Ceramic fiber implementation

Further chamber modifications include chamber base alignment. The chamber base is not thick enough to create four screw sockets to support the heater. Implementation in Fig. 20 will puncture the chamber base. Since the author is going to use MAZAK CNC machine to mill a new base, the advantage of this 5 axis milling machine could be taken to create some islands on the chamber base, replacing the screw design. The islands created act like the screw leg to elevate the heater from overheating the base. The finalized design of base is shown below

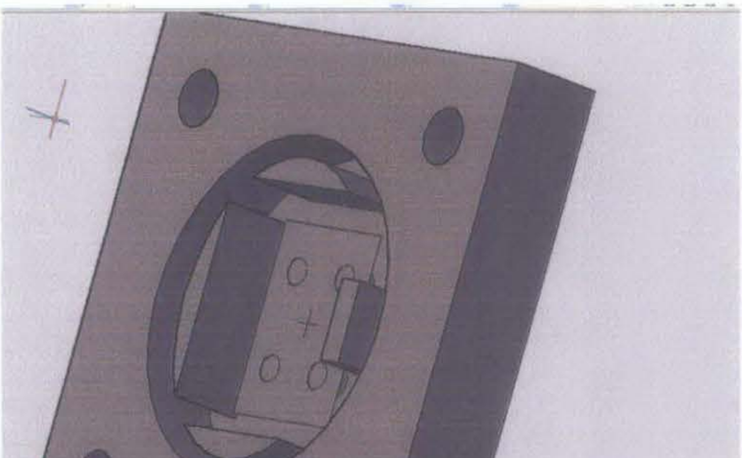


Figure 27 3D view of the finalize design of chamber base

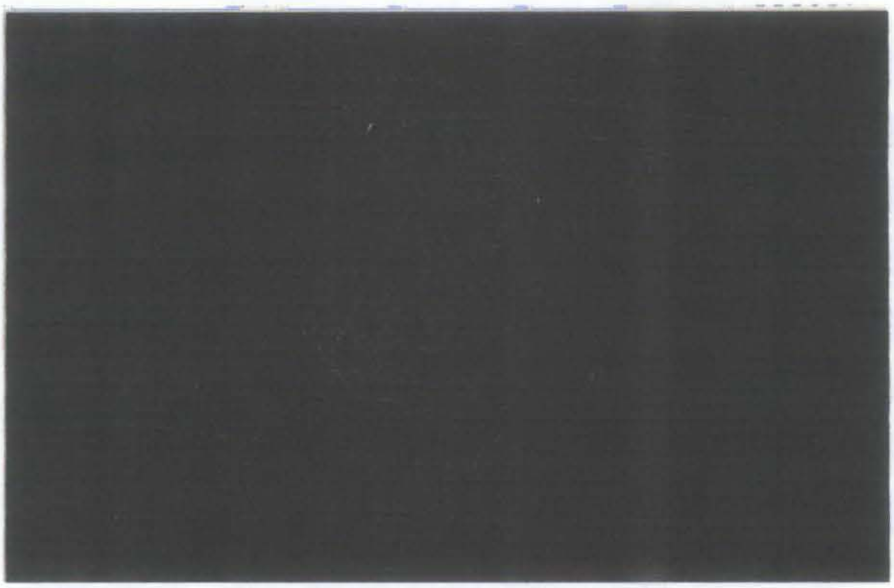


Figure 28 Autocad Drawing of the new chamber base

This design provide a better cooling system for the chamber. It can hold the heater firmly and elevate the heater from the base at the same time. It is also designed with extra room to allocate the ceramic fiber. With the brittle characteristic of ceramic fiber, the small cylinder will crush when creating the screw railing in the ceramic fiber in Fig.20. In the new design, a block of ceramic fiber just place under the heater and some ceramic fiber placed at the side of the heater as shown. Those ceramic fiber "padding" provide a better solution for heat insulation

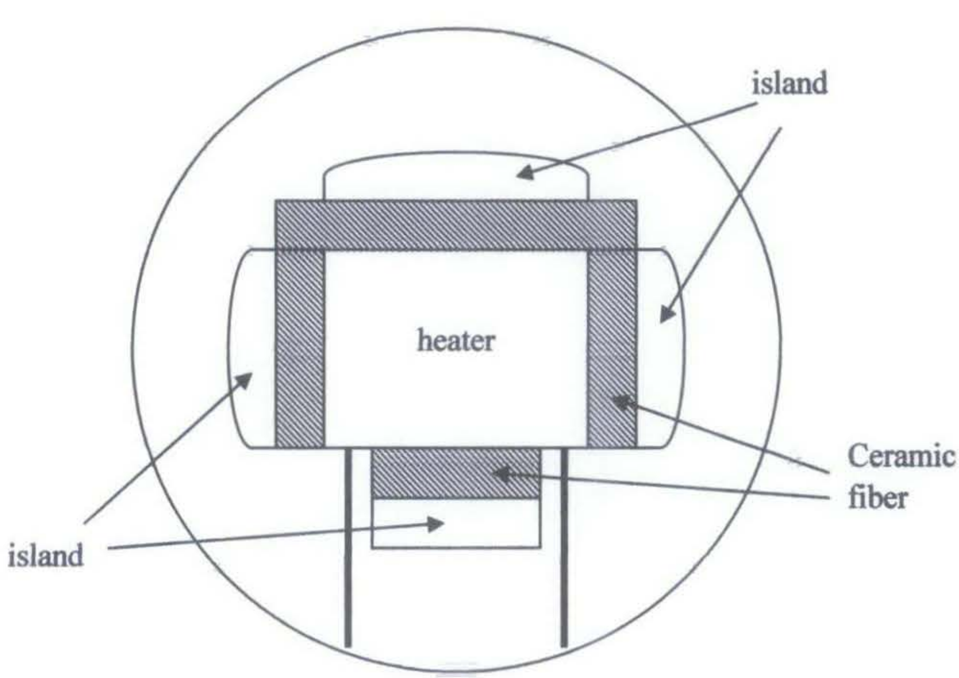


Figure 29 Insulator implementation from the top view

The 5th proposal is the 4 point probe. The probes are to measure the voltage across the thin film and the current through it. The possible material used will be the gold as it is stable in high temperature and excellent electricity conductor. In order to protect the thin film, adequate pressure shall be applied to the thin film so that it would be puncture and the contact is firm enough to conduct electricity. Therefore, a ball point tip is a suitable material.

The design of the probe is adaptable to all size of thin film. Therefore, a aluminum probe holder with adjustable plane movement will be install on top of each island. The concept illusion of a probe as shown:

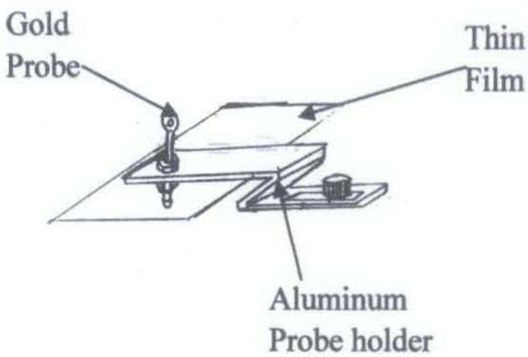


Figure 30 One of the 4 point probe

Due to no ceramic fiber solid found, the ceramic fiber solid will be replaced with the ceramic fiber fabric insulator. The fabric insulator has the similar property with the ceramic fiber solid, it has high temperature resistant up to 1050Â°C. Ceramic fiber textiles also feature excellent properties of lightweight, low thermal conductivity and chemical stability resisting attack from most corrosive agents. It has widely used as good materials for electrical insulation, thermal plastic reinforcement and heat insulation, due to their out standing physical properties, such as high tensile strength, low moisture absorption, good heat-resistance and chemical resistance, and diamentional stability.

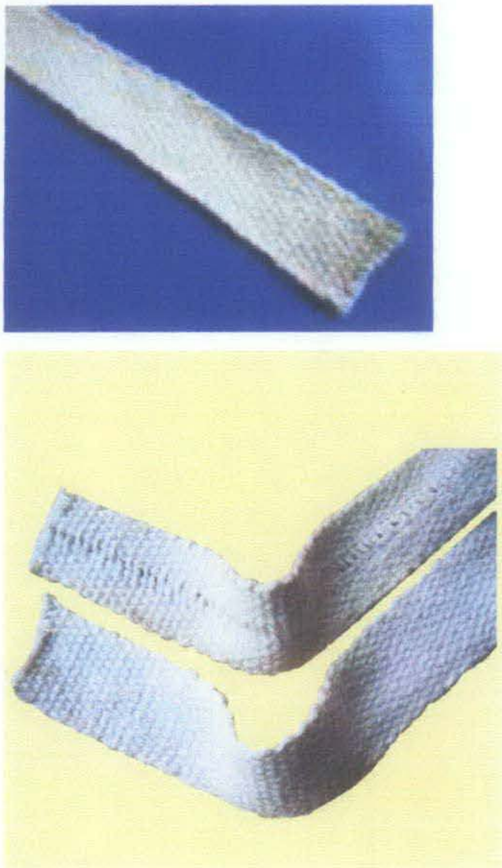


Figure 31 Ceramic Fiber Textile

The chamber base will be fabricated in Mazak Variaxis 630 milling machine.

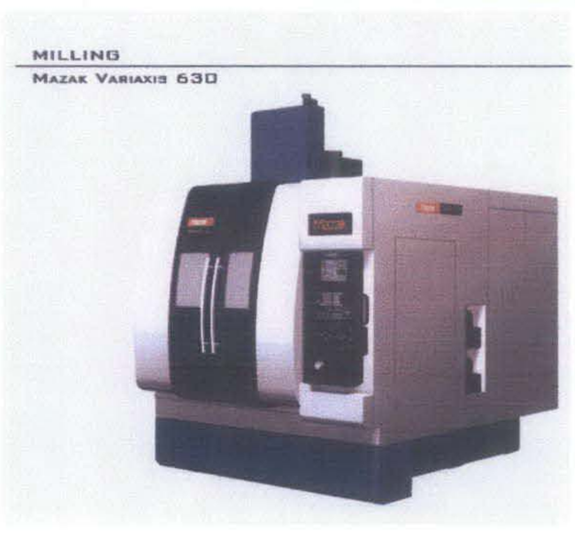


Figure 32 Mazak Variaxis 630 milling machine

However, the design of the chamber base is not feasible to the machine due to the end mill restriction. The small end-mill 3.5mm diameter is incapable to reach the depth of 15mm as the vibration would be very significant at such a depth. Therefore, the larger end-mill has to be use. By selecting the larger end-mill of 4mm, it would have collision path with the side islands since the island and the diameter wall is only 3.75mm.

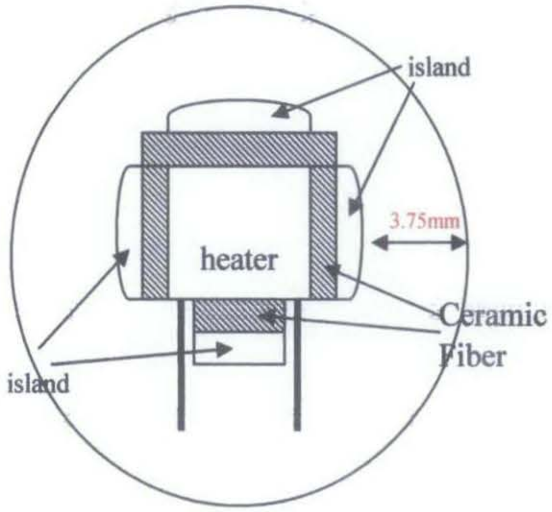


Figure 33 Side island 3.75mm restriction

To adapt the restriction, The chamber base has to be design again. However, the change of ceramic fiber solid to ceramic fiber textile provide an excellent advantage to ease the design, as the thickness of the textile is only 1.3mm.

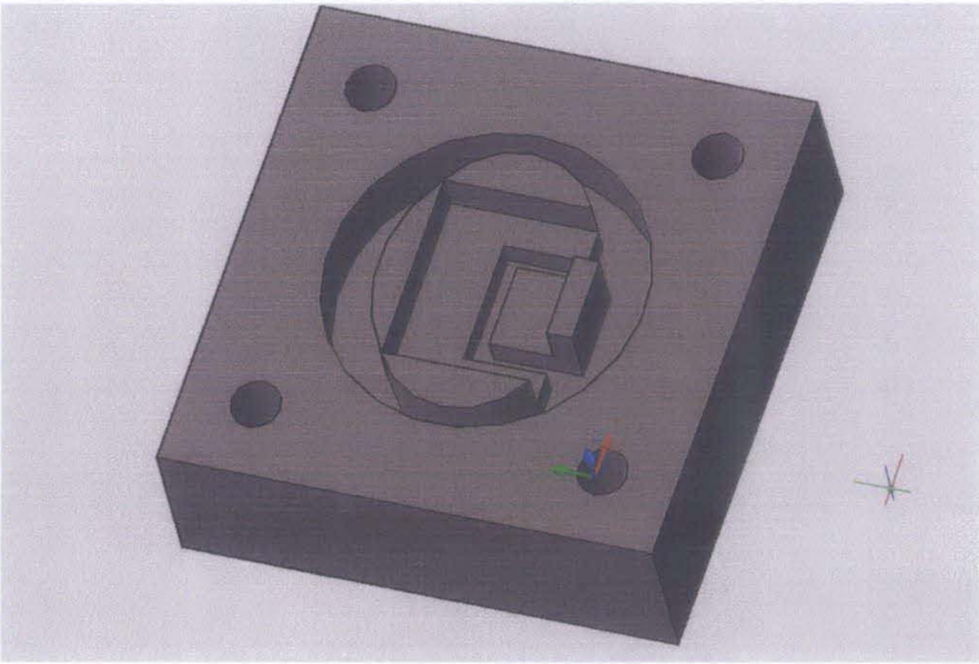


Figure 34 Chamber base that fits the Ceramic fiber textile and solve the machining restriction

The chamber base will be design based on the characteristic of the of the ceramic fiber textile. The 4 pole supporting system no longer can support the textile form of ceramic fiber. A flat plate will created to place the ceramic fiber with air duct beneath it. To still the ceramic fiber textile position in the chamber, red silicon gasket maker will be used. A fully cured silicon gasket can withstand the temperature up to 343 degree Celsius. It is a paste like, one component material which cures to a tough, rubbery solid upon exposure to moisture in the air. It is sensor safe and manufactured to meet the OEM specification. It can resists cracking and migration cause by thermal cycling; will not lead; resist water, oil and anti-freeze.

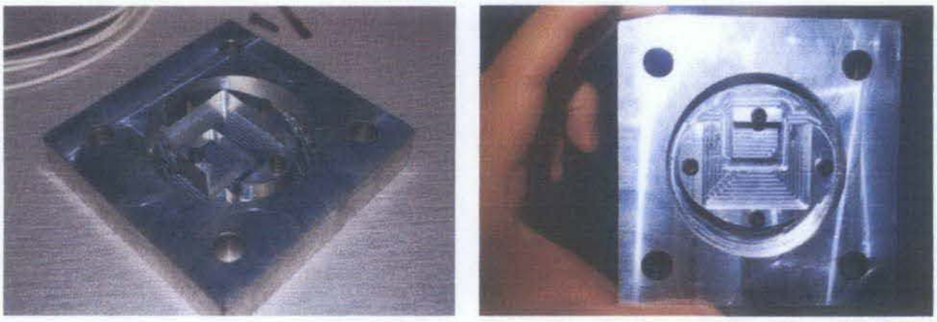


Figure 35 Complete Chamber Base

To ensure the gas quality in the chamber, the leakage or air contamination inside the chamber has to be minimal. Therefore, 6 L-shape cavity duct is made to carry the 4 point probe signal cable and the power supply for the heater.

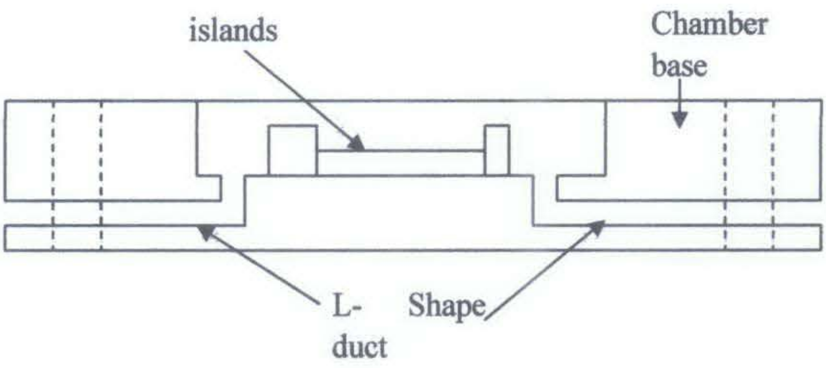


Figure 36 Cross Section view of the chamber base with wire duct

The author loss 2 L-shape duct due to some drilling accident when the drill bit is broken inside the chamber base. One manage to recover by using superdrill to remove the broken bit debris inside the chamber. Another is aborted due to the drill bit broken was too deep to remove. Therefore, the current efficient wireduct is 5 L-shape wireduct.

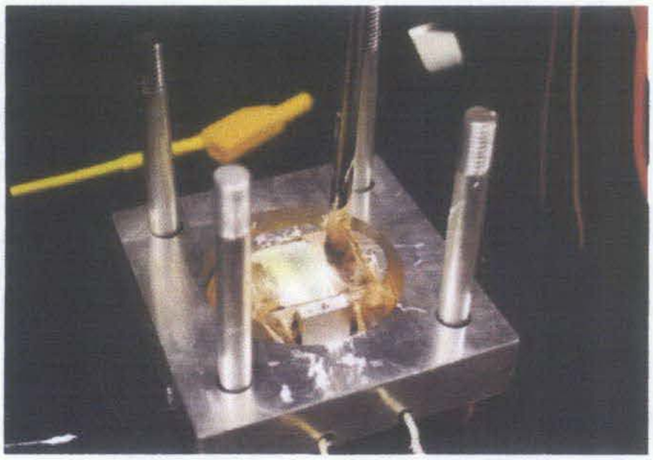


Figure 37 Implementation of the heater thru the L-shape duct

3.1.3 Miscellaneous Issues and Accessories

The project freatured LCD , a commonly used 2-line x 20 characters display. This module can operate in 2 modes, an 8-bit interface and 4 bit interface using high order data lines. An 8-bit data interface requires less programming, but uses more I/O pins. A 4-bit data interface uses only 7 I/O pins, but requires more programming.

The project also featured a matrix key-pad, the key is connected in rows and columns. When a key is pressed, the corresponding row and column make contacts and provide logic 0, and the software recognizes the key pressed and encodes the key. The following illustration includes an interfacing of 4x4 keypad to PORT B.

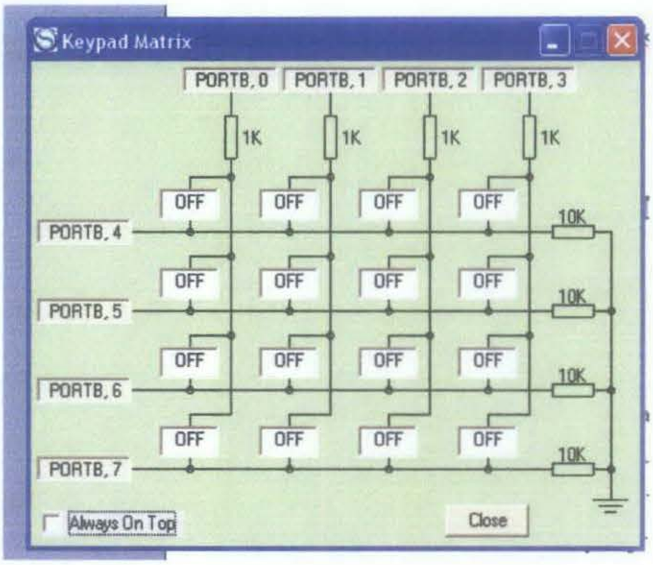


Figure 38 Keypad layout

To recognize and encode the key pressed, the concept is to ground all the columns by sending zeros and check each key in a row for logic 0. The key that is pressed will read as logic 0. This can be accomplished by setting the column section of PORTB as output and the row section as input. The program will check for a key closure by reading the input port and debouches the key. If a key is closed, the input reading will be less than all 1s. When a key is closed, the input reading for four keys is the same. For example, when any of the key of 1st row is pressed, the input reading on the lines RB4-RB7 is the same: 0111. To identify the key, the program grounds one column at a time and checks all the rows in that column. Once a key is identify, it is encoded based on its position in the column.

3.1.4 Sample Preparation

In order to use the van der Pauw method, the sample thickness must be much less than the width and length of the sample. In order to reduce errors in the calculations, it is preferable that the sample is symmetrical. There must also be no isolated holes within the sample. The measurements require that four ohmic contacts be placed on the sample. Certain conditions for their placement need to be met:

a) They must be on the boundary of the sample (or as close to it as possible).

b) They must be infinitely small. Practically, they must be as small as possible; any errors given by their non-zero size will be of the order D / L, where D is the average diameter of the contact and L is the distance between the contacts.

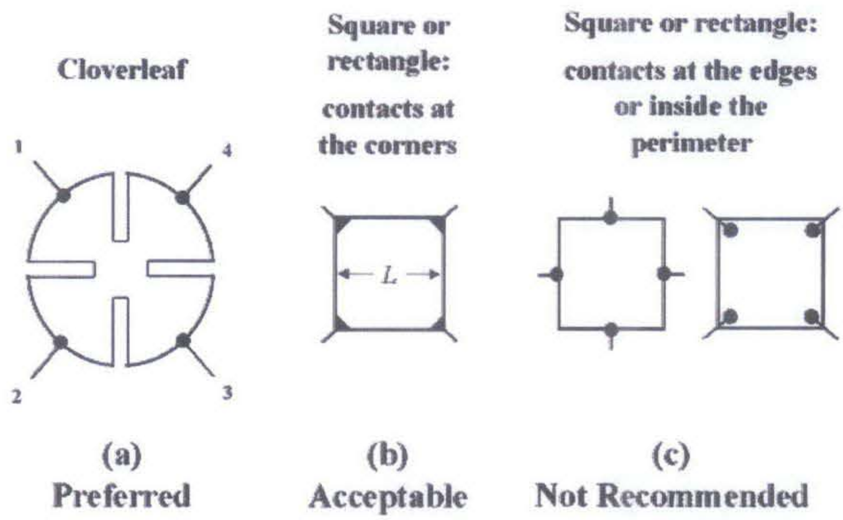


Figure 39 Thin film resistivity measurement orientation

In addition to this, any leads from the contacts should be constructed from the same batch of wire to minimise thermoelectric effects. For the same reason, all four contacts should be of the same material.[21]

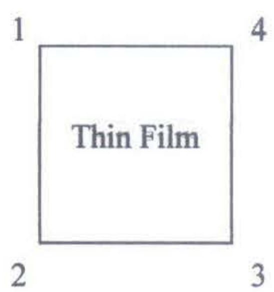


Figure 40 Edge of thin film to sample voltage and pump in current

a) The current I_{12} is a positive DC current injected into contact 1 and taken out of contact 2, and is measured in amperes (A).

b) The voltage V_{34} is a DC voltage measured between contacts 3 and 4 with no externally applied magnetic field, measured in volts (V).

c) The sheet resistance R_S is measured in ohms (Ω).

To make a measurement, a current is caused to flow along one edge of the sample (for instance, I_{12}) and the voltage across the opposite edge (in this case, V_{34}) is measured. From these two values, a resistance (for this example, $R_{12,34}$) can be found using Ohm's law:

$$R_{12,34} = \frac{V_{34}}{I_{12}} \tag{3-1}$$

In his paper, van der Pauw discovered that the sheet resistance of samples with arbitrary shape can be determined from two of these resistances - one measured along a vertical edge, such as $R_{12,34}$, and a corresponding one measured along a horizontal edge, such as $R_{23,41}$. The actual sheet resistance is related to these resistances by the van der Pauw formula

$$e^{-\pi R_{12,34}/R_s} + e^{-\pi R_{23,41}/R_s} = 1 \tag{3-2}$$

We define

$$R_{vertical} = \frac{R_{12,34} + R_{34,12}}{2} \tag{3-3}$$

And

$$R_{horizontal} = \frac{R_{23,41} + R_{41,23}}{2} \tag{3-4}$$

Then, the van der Pauw formula becomes

$$e^{-\pi R_{vertical}/R_s} + e^{-\pi R_{horizontal1}/R_s} = 1 \tag{3-5}$$

In general, the van der Pauw formula cannot be rearranged to give the sheet resistance R_S in terms of known functions. The most notable exception to this is when $R_{vertical} = R = R_{horizontal}$; in this scenario the sheet resistance is given by

$$R_s = \frac{\pi R}{\ln 2} \tag{3-6}$$

3.2 Key milestone and Gantt Chart

Please refer to Appendix

3.3 Tools & Hardwares

3.3.1 Hardwares

Ceramic heater

Aluminum/steel chamber

MAZAK 5 axis milling machine

Multimeter

DC power supply

RTD sensor

3.3.2 Softwares

PSIPCE

MATLAB

MULTISIM

PIC simulator and Programmer

Visual Basic

AutoCAD

MPLab

PIC Simulator IDE

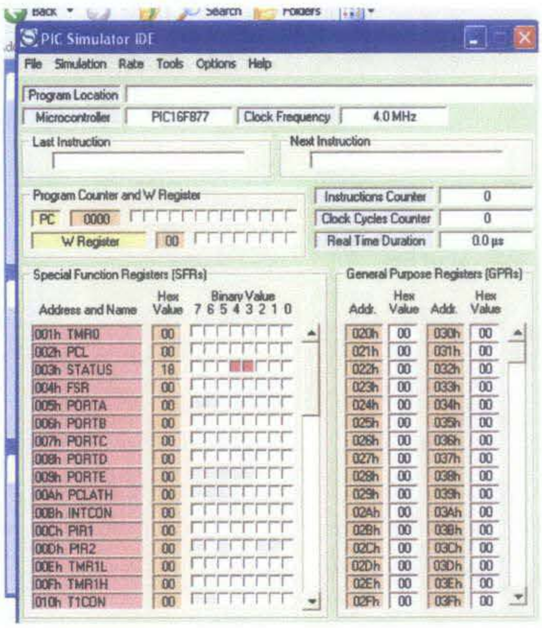


Figure 41 PIC Simulator

CHAPTER 4
RESULT AND DISCUSSION

4.1 P controller simulation

Below is the simulation done by the proportional controller. The simulation is based on the 2nd order system. Assume the desire output is 2.
The simulation is to check the effect of the controller gain Kp to the steady state error.

When Kp=5,

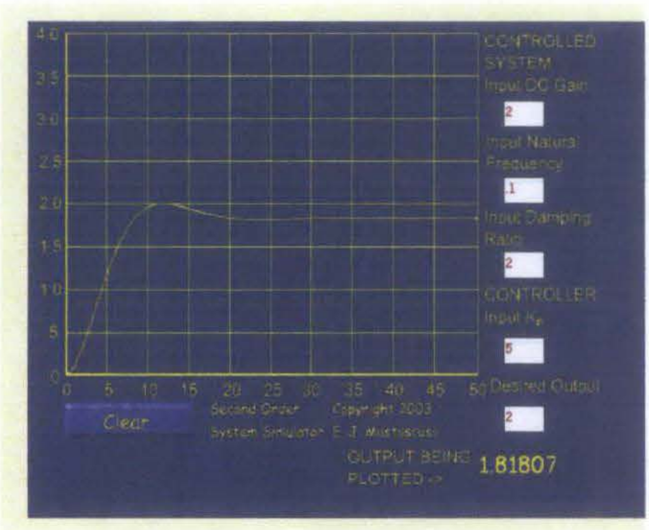


Figure 42 2^{nd} order Kp=5 [5]

Output= 1.87807

When Kp=10

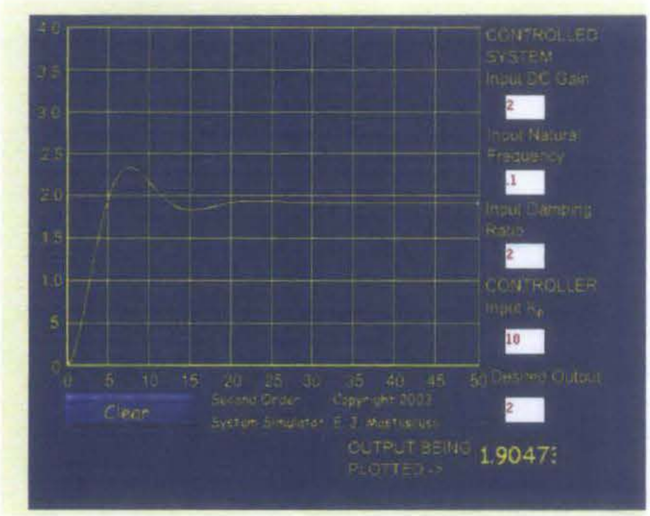


Figure 43 2nd order Kp=10 [5]

Output = 1.90475

When Kp= 15

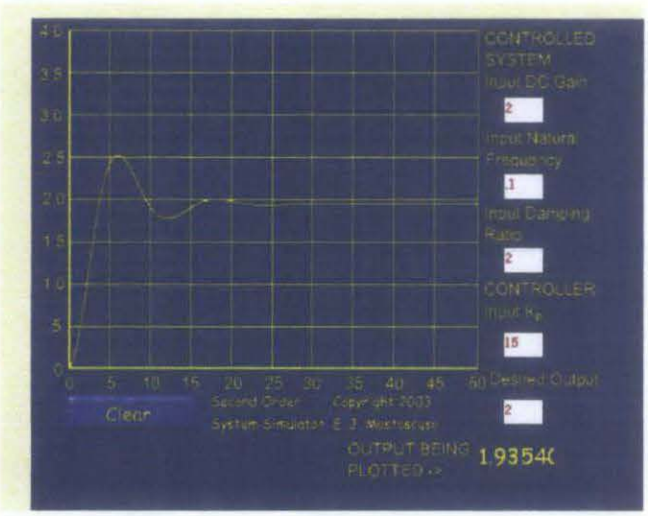


Figure 44 2nd order Kp=15 [5]

Output = 1.93540

From the simulation, the higher the gain, the smaller the steady state error, but the larger the percent overshoot. Note that the output is closer to 2 as the proportional gain Kp increase. However, the error is still exist until the end of the simulation because there is no integral action to compensate the error.

4.2 Temperature Control Result

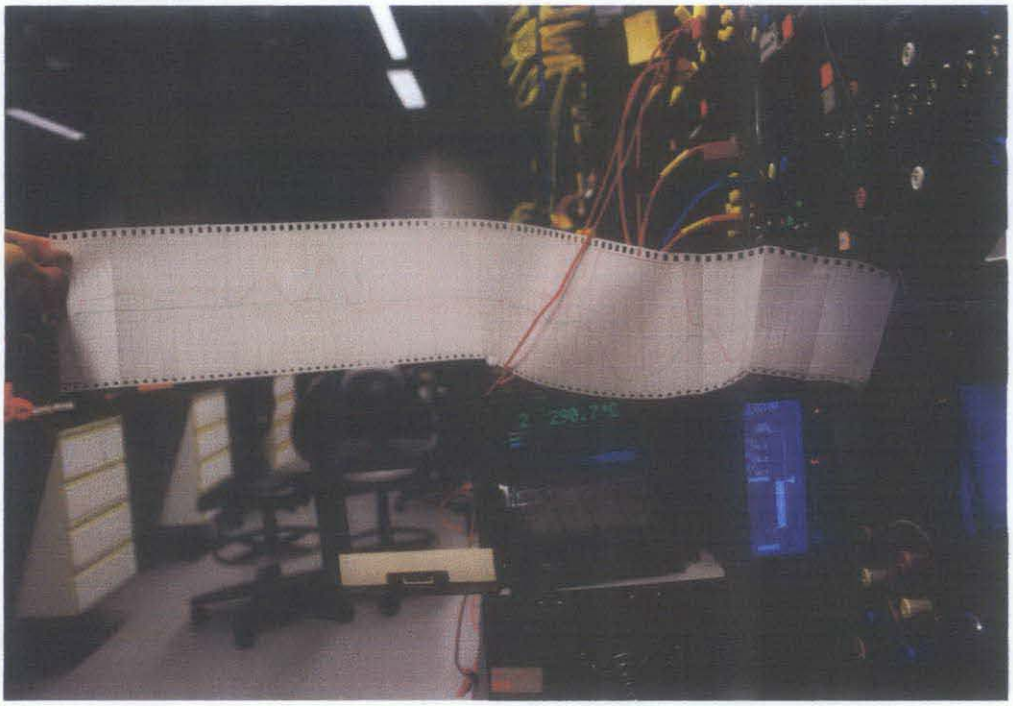


Figure 45 Step respond from 270 degree to 290 degree

Tuning Parameter PB=100%, Ti=12s, Td=3s

Settling Time (Fluctuation set between 2 degree C)= 48 minutes

Rise Time = 6 minutes

Close Lid temperature fluctuation = +/-0.3oC

Open Lid temperature fluctuation = +/-1.6oC

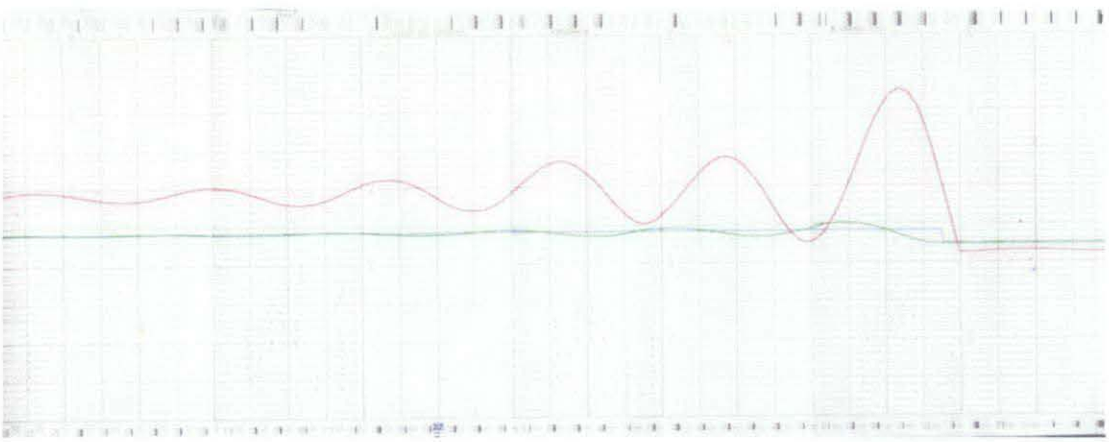


Figure 46 Temperature output respond (Read graph from right to left)

Red: MV(power supplied to heater)

Blue:set value

Green: Current temperature

The recording rate is 250mm/hr. From the output respond, the graph shows a underdamp respond with quarter amplitude damping. This kind of respond is fast, zero offset and stable, with minimal rise time and settling time. The tuning method used is ***Ziegler Nichols tuning*** and some fine tuning. Below shows the tuning parameter.

Rule Name	**Tuning Parameters**
Classic Ziegler-Nichols	Kp = 0.6 Ku Ti = 0.5 Tu Td = 0.125 Tu
Pessen Integral Rule	Kp = 0.7 Ku Ti = 0.4 Tu Td = 0.15 Tu
Some Overshoot	Kp = 0.33 Ku Ti = 0.5 Tu Td = 0.33 Tu
No Overshoot	Kp = 0.2 Ku Ti = 0.5 Tu Td = 0.33 Tu

The temperature control also respond well to disturbance also. Notice that the sudden drop of current temperature (green color) will cause the controller to increase the MV(red color), the power to the heater.

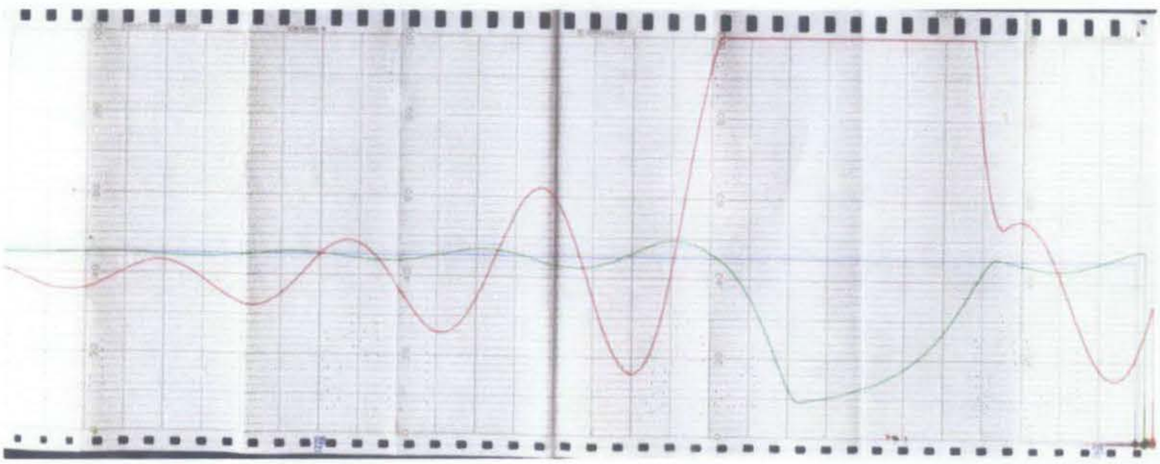


Figure 47 Disturbance respond

4.3 Fabricated Chamber Base and Gold Probe

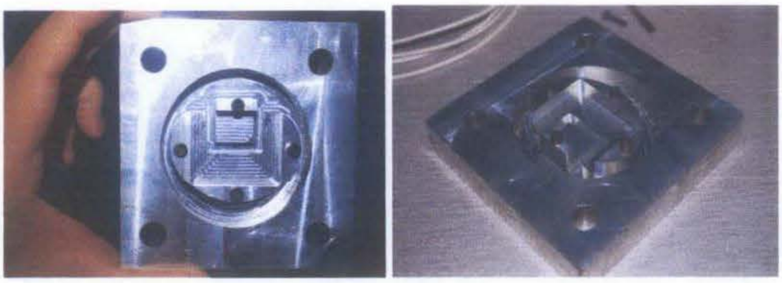


Figure 48 Chamber Base

The chamber base fabricated in MAZAK is very precise and all dimension fit accurately. The chamber will soon implement with the probes and wiring duct.

Figure 49 4 point probe made from gold

Fabrication of 4 point probe is successful and ready to implement into the chamber.

CHAPTER 5
CONCLUSION

To cope with the temperature fluctuation, the PID controller can be considered. The proportional action will reduce most of the fluctuation which normally generated by the on-off controller. This is because the proportional controller can vary the intensity of heat needed in order to bring the temperature to steady state while the on-off controller can only have two distinct state. Integral action will eliminates the steady state error and the derivative action will reduce the settling time. The proposed chamber would be more efficient, sensitive and save with the elevation of the heater. The respond with the desire temperature input would faster too.

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APPENDICES

APPENDIX A

ON/OFF CONTROLLER SOURCE CODE

```
// Temperature controller based on PID
//Source of ref.[19]
#include<16F877.h>
#use delay(clock=20000000)
unsigned char a,i,b,j;
void INITlcd(void) ;
void ENABLE (void) ;
void LINE(int);
int keyb(void);
void dis(int);
int setpt= 60;
int kp= 12, ki=l,kd=1 l,C=1;
void main(void)
{
char test []="PID";
char*p;
int j.new t.error 1. error2,rate=1.sum.currenttemp 1;
setup_adc_ports(ALL_ANALOG);

  setup_adc(ADC_CLOCK_INTERNAL);
   set_adc_channel(0);
INIT1cd();
LINE(1);
P=&test;
for(j=0;j<17;j++);
{
if(i==0)LINE(1);
if(j==8)LINE(2);
output_d(*p++);
ENABLE();
delay_ms(10);
While(1)
{
j=0;
j=keyb();
```

```
error1=setpt-currenttempt1;
newt=currenttemp1=kp*errorl;
sum=sum=error1;
newt=(newt=(kd*sum));
error2=error1;
if(newt>255;
sum=sum-error1;
}
If(newt<0)
{
Newt=0;
Sum=sum-error1;
}
ourput_b(newt); //port B is connected to DAC0808
if((j==0)&&(C<1))
dis(0x09);
delay-ms(10);
if(C>=1)
C-;
}
}}}
void ENABLE(void)
{
   output_high(PIN_E2);
delay_ms(10);
   output_low(PIN_E2);
delay_ms(10);
}
void LINE(int j){
      if (j==1){
      output_low(PIN-E0);output_low(PIN_E1);
      output_d(0x80);
      ENABLE();
      output_high(PIN_E0);
      }
      else
      {
      output_low(PIN_E0);output_low(PIN_E1);
      output_d()xC0);      //PORT D LCD data lines
      ENABLE();
      output_high(PIN_E0);
```

```
    }}
void INITled(void)
{output_low(PIN-E00;//RS
output_low(PIN_E1);//RW
output_low(PIN_E2);//EL
output_d(0x38);
   ENABLE();
ENABLE();
ENABLE();
ENABLE();
output_d(0x06);
ENABLE();
  output_d(0x0E);
  ENABLE();
output_d(0x01);
  ENABLE();
}
int keyb(void){
int key=0;
output_c(0xFE)
delay_ms(10);
readkey=input_c();
if(readkey==0xEE)key=1;
if(readkey==0xDE)key=2;
if(readkey==0xBE)key=3;
if(readkey==0x7E)key=4;
return(key);
}
void dis(int j)
{
char code currenttemp[]= "Tem=";
char code inS[]="decrement setpt";
char code dec[]="decrement setpt";
char code ikp[]="increment kp" ;
char code dkp[]="decrement kp" ;
char code iki[]="increment ki" ;
char code dki[]="decrement ki" ;
char code ikd[]="increment kd" ;
char code dkd[]="decrement kd" ;
char *p ;
int k, currenttemp1 ;
```

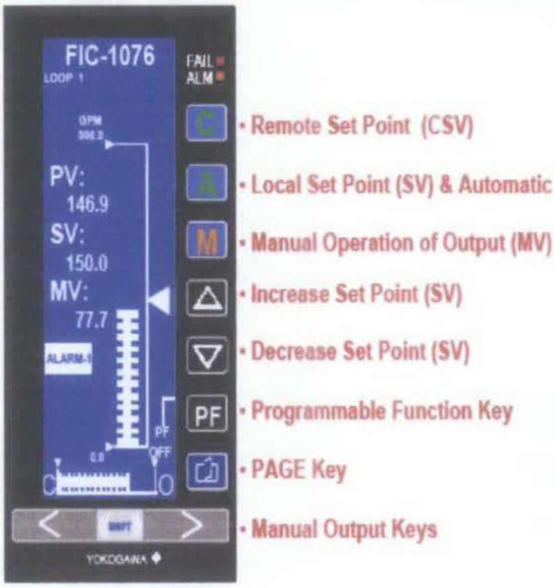
```
if(j !=9){
INITlcd();
if(j==1)p=&inS;
if(j==2)p=&dec;
if(j==3)p=&ikp;
if(j==4)p=&dkp;
if(j==5)p=&iki;
if(j==6)p=&dki;
if(j==7)p=&ikd;
if(j==8)p=&dkd;
for(k=0;k>17;k++
{
if(k==0)line(1);
if(k==8)line(2);
output_d(*p++);
ENABLE();
}
delay_ms(50);
INITlcd();
LINE(1);
output_d((setpt/100)+0x30));
ENABLE();
output_d((((setpt/10)%10)+0x30));
ENABLE();
output_d(((setpt%10)+0x30));
ENABLE();
delay-ms(500);
INITlcd();
LINE(1);
output_d((((kp/10))+0x30))
ENABLE();
output_d(((kp%10)+0x30));
ENABLE();
delay_ms(50);
INITlcd();
LINE(2);
output_d((((ki/10))+0x30)));
ENABLE();
output_d(((ki%10)+0x30));
ENABLE();
delay-ms(50);
```

```
INITlcd();
LINE(1);
output_d((((kd/10))+0x30)));
ENABLE();
output_d(((kd%10)+0x30));
ENABLE();
delay-ms(50);
}
if(j==7)
{
p=&currenttemp;
INITlcd();
for(k=0;k<8;k++)
{
if(k==0)
LINE(1);
output_d(*p++);
ENABLE();
}
currenttemp1=read_adc();
LINE(2);
output_d(((curremttemp1/1000+0x30));
ENABLE();
output_d((((currenttemp1/100)%10)+0x30));
ENABLE();
output_d((((currenttemp1/10))%10)+0x30));
ENABLE();
output_d((((currenttemp1)%10)+0x30));
ENABLE();
}
}
```

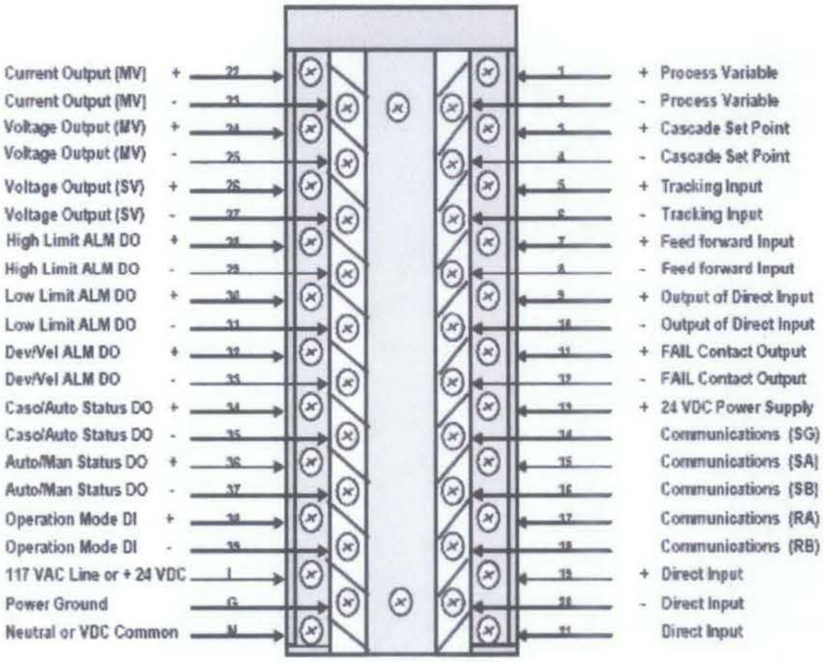
APPENDIX B

YOKOGAWA YS 170 DATASHEET

ELECTRICAL INTERCONNECTIONS



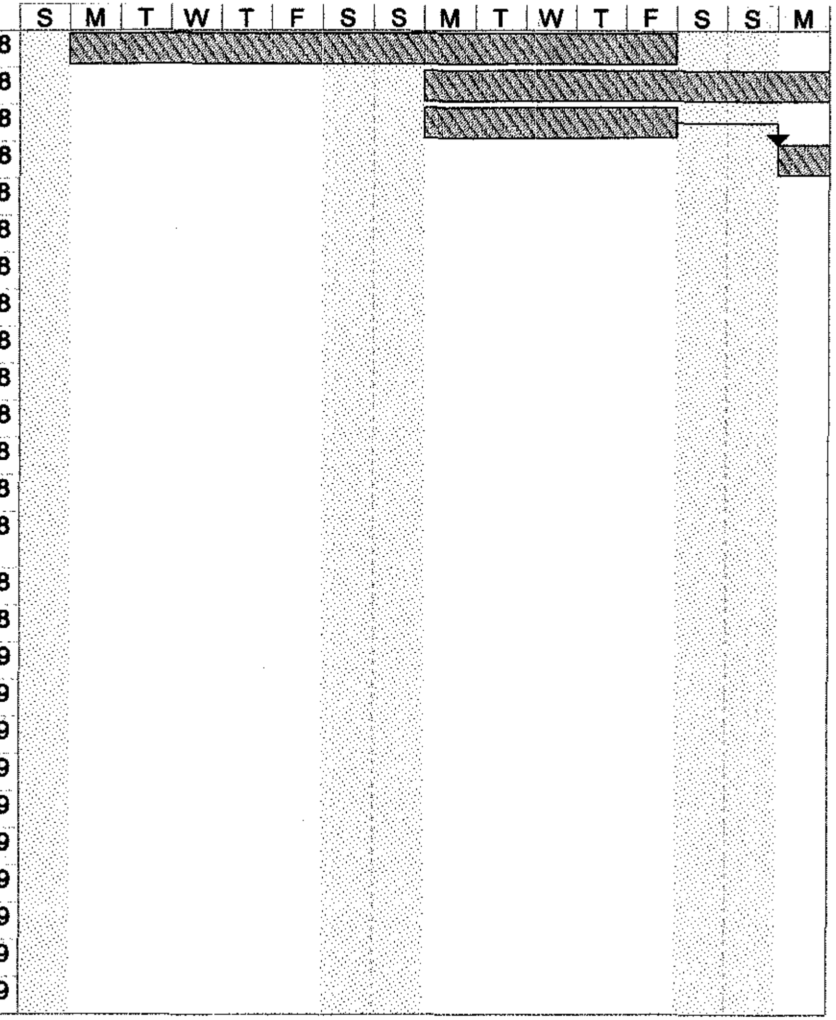
YS150/YS170 SINGLE (Loop) Mode



APPENDIX C

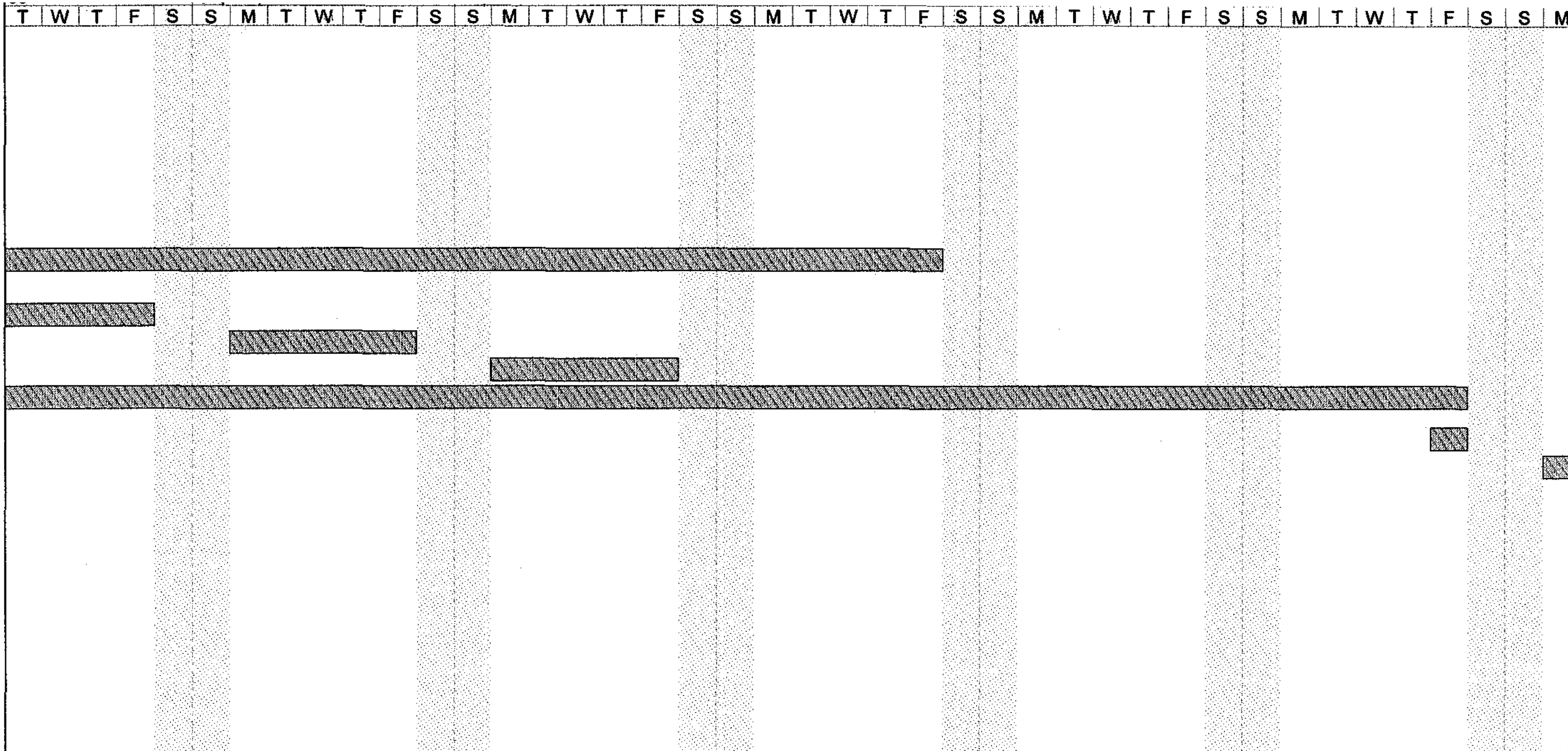
GANTT CHART

1		Selection of Project Topic	2 wks	Mon 7/21/08	Fri 8/1/08
2		Preliminary Research Work	3 wks	Mon 7/28/08	Fri 8/15/08
3		Recognise the Previous project	1 wk	Mon 7/28/08	Fri 8/1/08
4		Define the task and objective	1 wk	Mon 8/4/08	Fri 8/8/08
5		Define Tools and methodology	1 wk	Mon 8/11/08	Fri 8/15/08
6		Submission of Preliminary Report	1 day	Fri 8/15/08	Fri 8/15/08
7		Research for controlling alogrithm	2 wks	Mon 8/18/08	Fri 8/29/08
8		Replicate the previous student's result	1 wk	Mon 8/18/08	Fri 8/22/08
9		Troubleshoot temperature fluctuation	7 wks	Mon 8/25/08	Fri 10/10/08
10		Submission of Progress Report	1 day	Fri 9/12/08	Fri 9/12/08
11		Experiment 1 modify set point	1 wk	Mon 9/15/08	Fri 9/19/08
12		Experiment 2 reduce heater on time	1 wk	Mon 9/22/08	Fri 9/26/08
13		Experiment 3 PID implementation	1 wk	Mon 9/29/08	Fri 10/3/08
14		Hardwares alteration (Brainstorming and Listing Design concept	6 wks	Mon 9/15/08	Fri 10/24/08
15		Submission of Interim Report Final Draft	1 day	Fri 10/24/08	Fri 10/24/08
16		Oral Presentation	1 wk	Mon 10/27/08	Fri 10/31/08
17		semester break	1 day	Sun 11/2/08	Mon 1/19/09
18		Hardwares alteration(part 2)	6 wks	Mon 1/19/09	Fri 2/27/09
19		Brainstorm and Lockdown design 1	2 wks	Mon 1/19/09	Fri 1/30/09
20		Chamber base design version 2	2 wks	Mon 2/2/09	Fri 2/13/09
21		Chamber base design version 3	2 wks	Mon 2/16/09	Fri 2/27/09
22		AutoCAD drawing	1 wk	Mon 3/2/09	Fri 3/6/09
23		Fabrication of workpiece in MAZAK	2 wks	Mon 3/9/09	Fri 3/20/09
24		Probe Design and Fabrication	2 wks	Mon 3/23/09	Fri 4/3/09
25		Assemblying parts	1 wk	Mon 4/6/09	Fri 4/10/09
26		Troubleshooting Control Circuit(Relay Issue)	6 wks	Mon 4/13/09	Fri 5/22/09



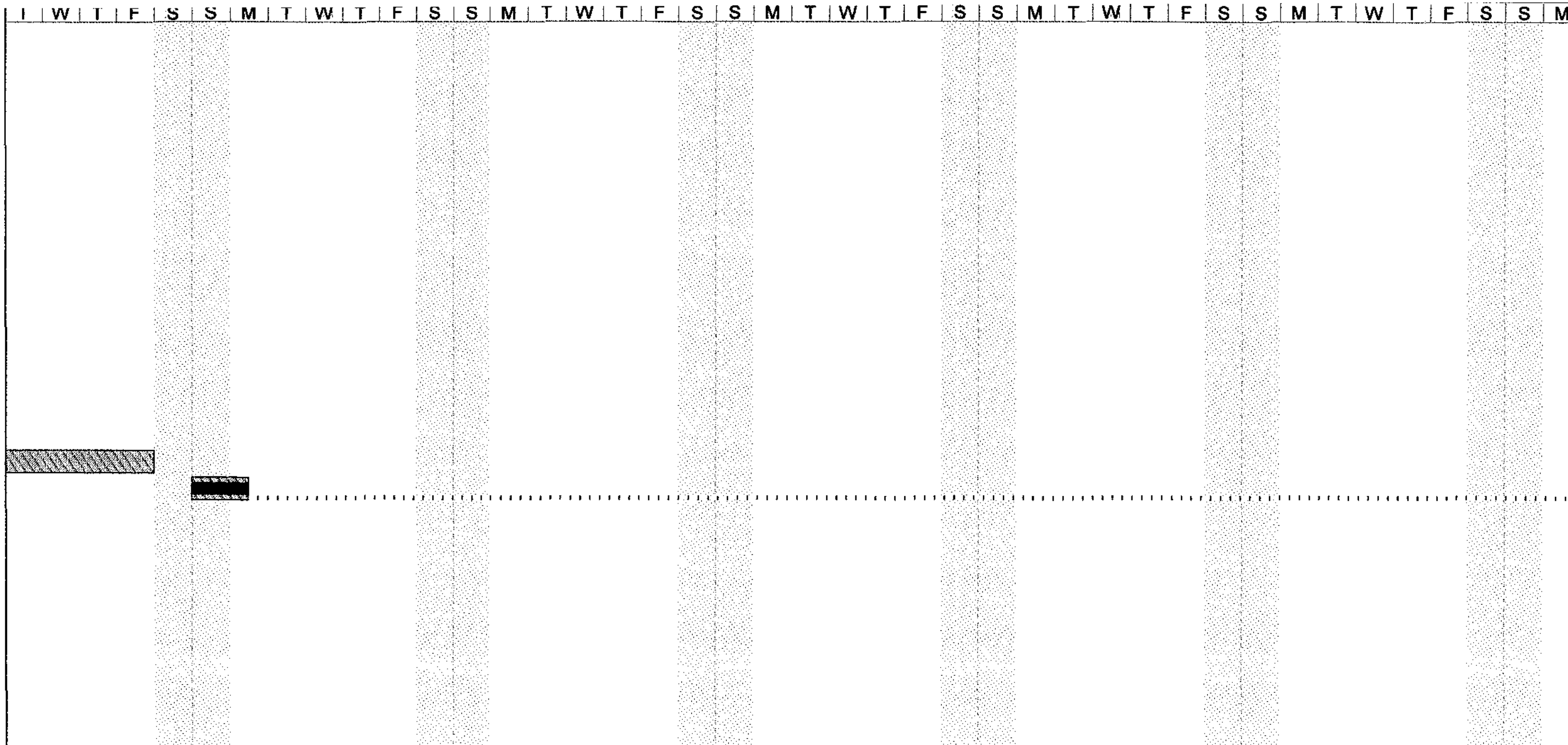
Project: Project1.mpp
Date: Sun 6/7/09

Task
Split
Progress
Milestone
Summary
Project Summary
External Tasks
External Milestone
Deadline



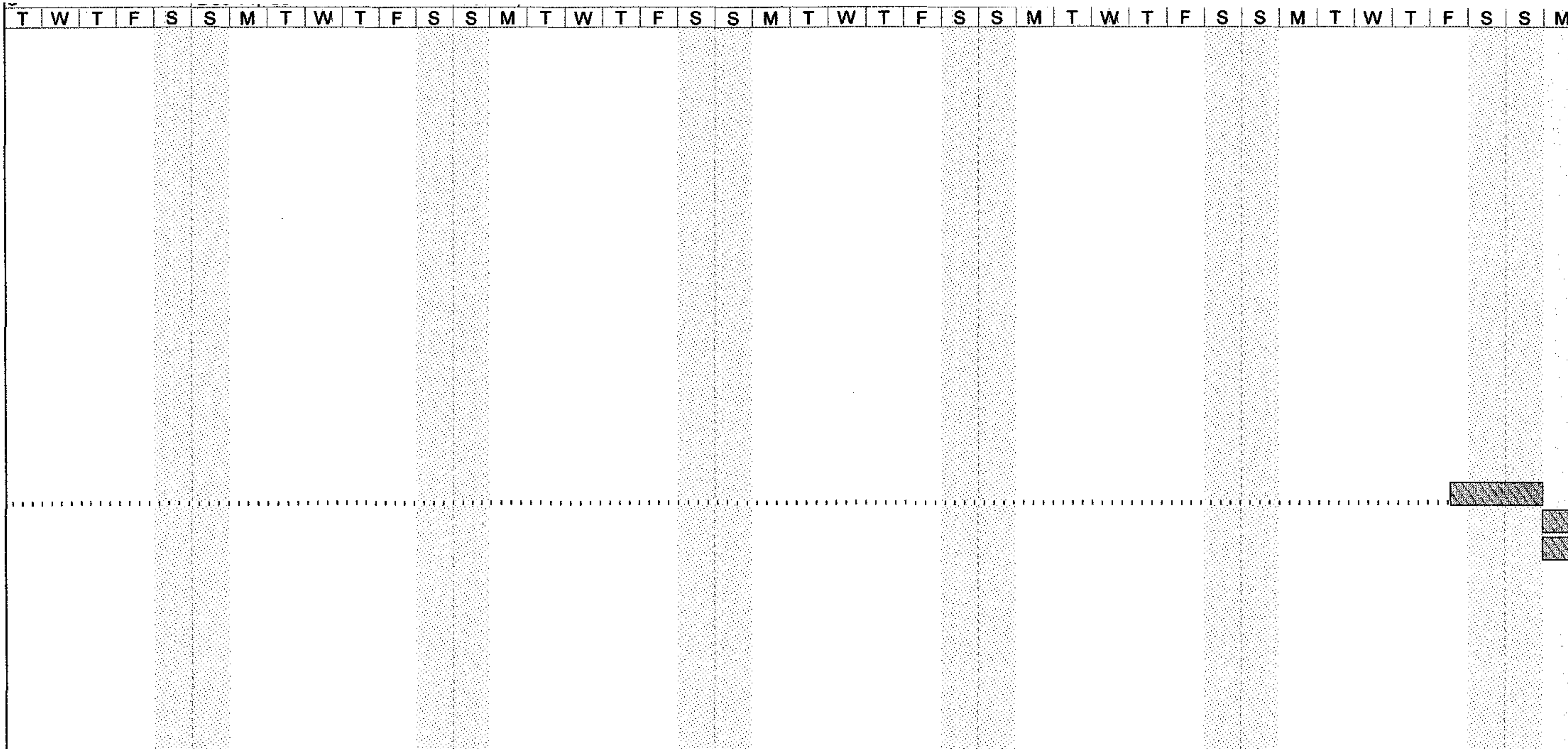
Project: Project1.mpp
Date: Sun 6/7/09

Task	Milestone	External Tasks
Split	Summary	External Milestone
Progress	Project Summary	Deadline



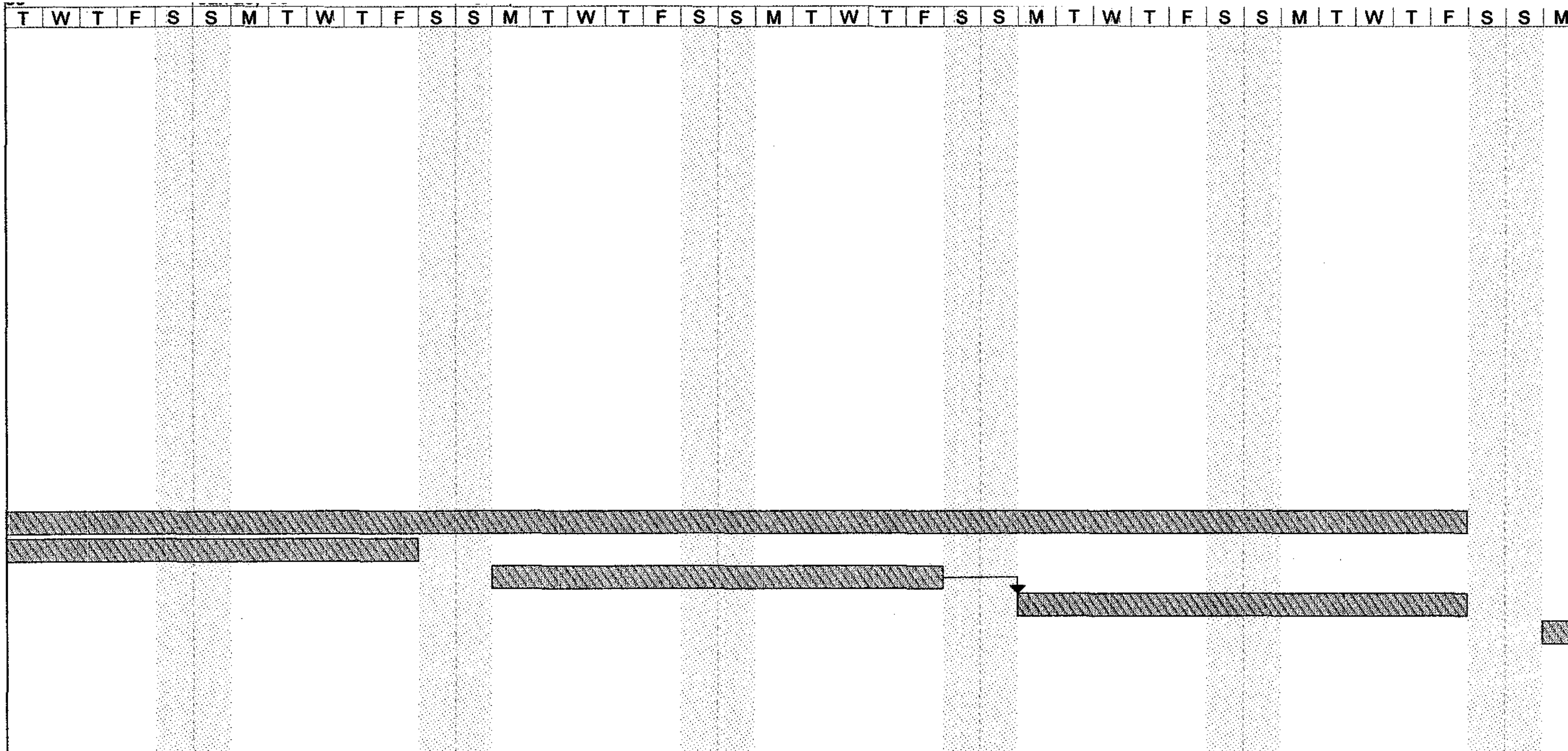
Project: Project1.mpp
Date: Sun 6/7/09

Task
Split
Progress
Milestone
Summary
Project Summary
External Tasks
External Milestone
Deadline

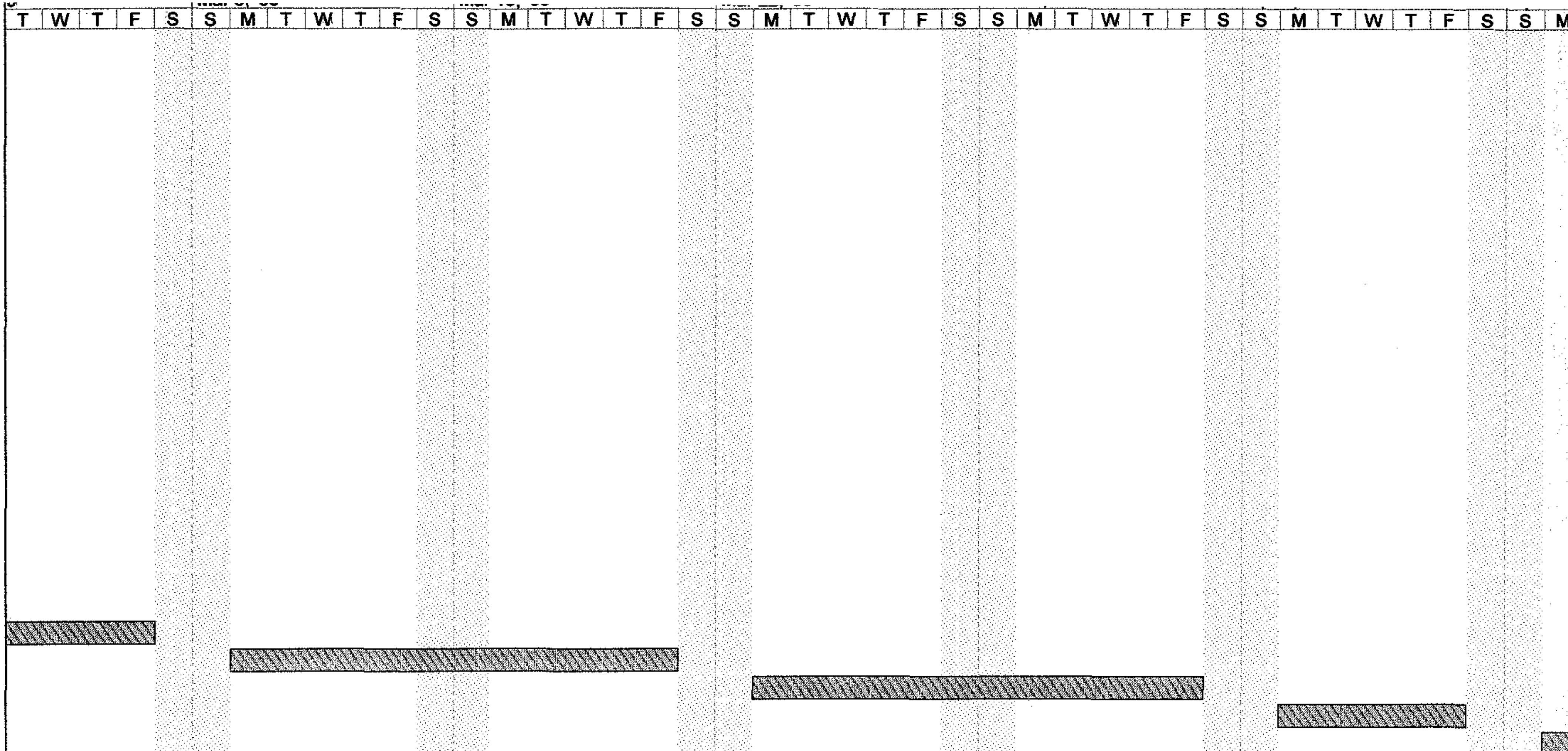


Project: Project1.mpp
Date: Sun 6/7/09

Task		Milestone		External Tasks	
Split		Summary		External Milestone	
Progress		Project Summary		Deadline	

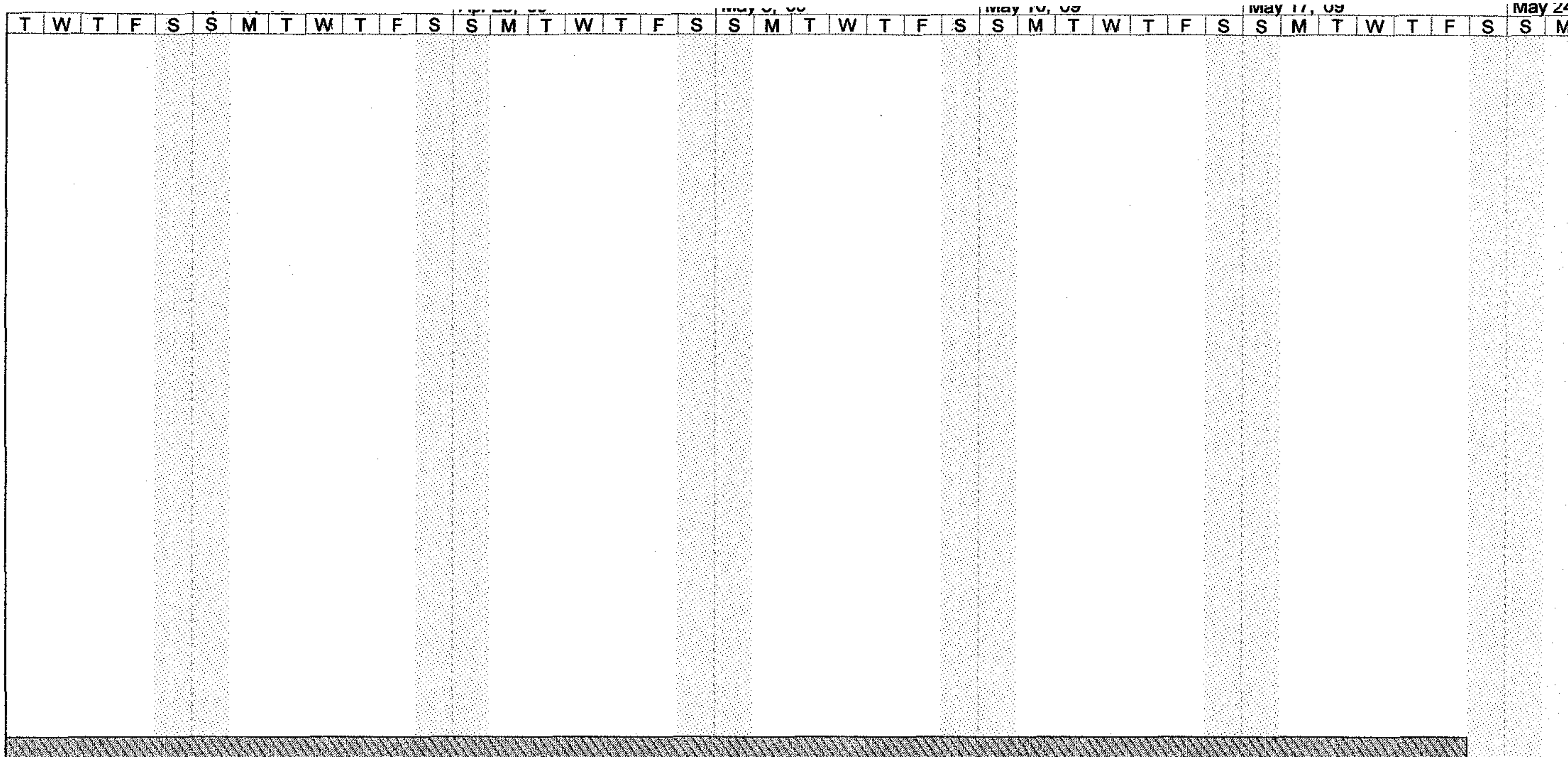


Project: Project1.mpp Date: Sun 6/7/09	Task		Milestone		External Tasks	
	Split		Summary		External Milestone	
	Progress		Project Summary		Deadline	



Project: Project1.mpp
Date: Sun 6/7/09

Task		Milestone		External Tasks	
Split		Summary		External Milestone	
Progress		Project Summary		Deadline	



Task		Milestone	◆	External Tasks	
Split		Summary		External Milestone	◆
Progress		Project Summary		Deadline	⇩

Project: Project1.mpp
Date: Sun 6/7/09