DOKUZ EYLÜL UNIVERSITY

GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES

TEMPERATURE CONTROL SYSTEM WITH FUZZY LOGIC AND RF CONTROL

by

Serdar TOPÇUOĞLU

October, 2007

İZMİR

TEMPERATURE CONTROL SYSTEM WITH FUZZY LOGIC AND RF CONTROL

A Thesis Submitted to the
Graduate School of Natural and Applied Sciences of Dokuz Eylül University
In Partial Fulfillment of the Requirements for the Degree of Master of Science
in Electrical and Electronics Engineering

by
Serdar TOPÇUOĞLU

October, 2007
İZMİR

M.Sc THESIS EXAMINATION RESULT FORM

We have read the thesis entitled **"TEMPERATURE CONTROL SYSTEM WITH FUZZY LOGIC AND RF CONTROL"** completed by **SERDAR TOPÇUOĞLU** under supervision of **ASSIST.PROF. DR GÜLDEN KÖKTÜRK** and we certify that in our opinion it is fully adequate, in scope and in quality, as a thesis for the degree of Master of Science.

....

Yrd. Doç. Dr Gülden Köktürk

....

(Jury Member) (Jury Member)

Prof. Dr. Cahit HELVACI
Director
Graduate School of Natural and Applied Sciences

ACKNOWLEDGEMENTS

This thesis would not have been possible without the kind support, the trenchant critiques, the probing questions, and the remarkable patience of my thesis advisor – Assist.Prof. Dr. Gülden Köktürk.

Finally yet importantly, I offer my sincere thanks to my loving family. Throughout all my endeavors, their love, support, guidance, and endless patience have been truly inspirational. This thesis is simply impossible without them.

Serdar TOPÇUOĞLU

TEMPERATURE CONTROL SYSTEM WITH FUZZY LOGIC AND RF CONTROL

ABSTRACT

In the near future, it is important that designing and producing new product which consume less energy. In this thesis, system design that reduces power consumption in temperature control systems is being researched. Fuzzy logic is used in this system to reduce power consumption. Using fuzzy logic in the temperature control systems introduces new systems that consume less energy and intelligent. Fuzzy logic table is constituted and practiced on temperature control system. Conclusions of this system are compared with normal systems. It is observed that the system consumes less energy than normal systems. The system runs better than normal systems with less energy consumption and less temperature changing.

Besides less energy consumption, consumers want to control new products from distance and wireless. They want to be in interaction with the product by using Radio frequency communication systems. In this thesis, radio communication application is practiced and two systems are connected each other with transmitter and receiver modules. The connection working is investigated. In first section, data that is taken from outside is sent to the system continual and it is informed about changing of outside. This section is automatic energy saving mode and user cannot effect to the system. In second section, data that is taken from user is sent to the system. So the system's performance is arranged in respect to user. Conclusions of both sections are investigated and they are compared with normal systems. It is observed that the rf systems run more performance than normal systems

Keywords : Fuzzy logic, fuzification, defuzification, snubberless, offset, proportional, derivative, integral, wavelength, receiver, transmitter, modulation

BULANIK MANTIK VE RF KONTROLLÜ ISI KONTROL SİSTEMİ

ÖZ

Günümüzde enerji tüketimi az olan ürünlerin tasarlanması ve üretilmesi önemli bir olgudur. Bu nedenle, bu tezde ısı kontrol sistemlerinde enerji tüketimini azaltan bir sistem yapısı incelenecektir. Enerji tüketiminin azaltılması için bu sistemde bulanık mantık yaklaşımı kullanılmıştır. Bu yaklaşımın ısı kontrol sistemlerinde kullanılması, akıllı ve enerji tüketimi az sistemleri ortaya çıkarmıştır. Isı kontrol sistemi için bulanık mantık tablosu oluşturulmuş ve sisteme uygulanmıştır. Sistemin çalışması sonucunda elde edilen sonuçlar normal çalışma sitemleriyle karşılaştırılmıştır. Bulanık mantık çizelgesi sayesinde sistemin gerektiğinden az enerji tüketimi yaptığı gözlenmiştir. Enerji tüketimini azaltma ve ısı değişkenliğinin az olması sistemi normal sistemlerden daha iyi yapmaktadır.

Enerji tüketimin az olmasından başka ürünle uzaktan etkileşimde bulunmak ürün tasarımında aranılan özellikler arasına girmiştir. Radyo frekansı haberleşme teknolojisi ile ürünlerle uzaktan etkileşimde bulunulmaktadır. Bu tezde radyo haberleşme uygulaması yapılmış ve iki sitem arasında verici ve alıcı modüller ile bağlantı yapılarak çalışma incelenmiştir. İlk aşamada dış ortamdan alınan veri sisteme sürekli gönderilir ve dış koşulların değişiminden sistem bilgilendirilir. Bu aşama kullanıcının etki etmediği otomatik enerji tüketimi yapılan kısımdır. İkinci aşamada sisteme kullanıcının istediği dış değerler gönderilir. Böylece sistem performansını kullanıcıya göre ayarlamış olur. Her iki aşamanın sonuçları incelenmiş ve her ikisininde de normal sistemlere göre daha performanslı çalıştığı gözlenmiştir.

Anahtar kelimeler : Bulanık mantık, bulanıklaştırma, netleştirme, tersleme, kaydırma, oransal, türevsel, integral, dalgaboyu, alıcı, verici, modülasyon.

CONTENTS

CHAPTER ONE
INTRODUCTION

In recent years, the power saving is important for our life. Producers and designers are producing new products that is intelligent and spending less energy. There are a lot of examples for the new products. They are intelligent white goods, mobile phones that have long battery charge, digital electronic products that have more memory, economic cars that consume less fuel. Products that are in every sector are being updated and they become intelligent and wireless. People want their products to consume less energy and they want to affect them from distance. The systems that have power saving feature is called intelligent systems. They can interact with user and they provide comfort for them. They are user-friendly products. People prefer these systems than normal systems. Because users want to affect these products from distance and they want to use them easily.

In the literature, different control methods have been developed and performed to control the systems that cosume power like on-off control, Proportional control. (Webb, 1964 – Harriot, 1964 – Patrick, 1997 – Anderson, 1998 – McMillian, 1999). However, there is disadvantage in on-off control system for power saving. The systems that work with on-off control consume more power and energy.

Intelligent systems take data from outside and inside. Data is processed in system with structure that defines in the beginning and system gives out optimum conclusion which user wants. Data can be processed with structure like fuzzy logic, expert systems, neural network. In this thesis, fuzzy logic structure is used to process data.

Basically, Fuzzy Logic (FL) is a multivalued logic, that allows intermediate values to be defined between conventional evaluations like true / false, yes / no, high / low, etc. (Zadeh, 1965). Notions like rather tall or very fast can be formulated mathematically and processed by computers, in order to apply a more human-likeway of thinking in the programming of computers. Fuzzy systems is an alternative to traditional notions of set membership and logic. Fuzzy Logic has emerged as a profitable tool for the controlling and steering of systems and complex industrial processes, as well as for household and entertainment electronics, as well as for other expert systems and applications.

Fuzzy logic is different from normal logic. Normal logic has crisp results like 0 or 1. Fuzzy takes these results and fuzificates to between 0 and 1. Data is processed between 0 and 1. Then, the data is defuzificated and crisp results are reached again like 0 and 1. Normal logic works in crisp results but fuzzy logic can process the data between 0 and 1. Fuzzy finds set of data with membership function and process the data in this set. Membership function is defined by linguistic variables. Cold – Hot crisp results can be fuzzy results like Very cold – cold – normal – hot – very hot by using membership function. They are shown at Figure 1.1. So system works like intelligent and gives out the best result.

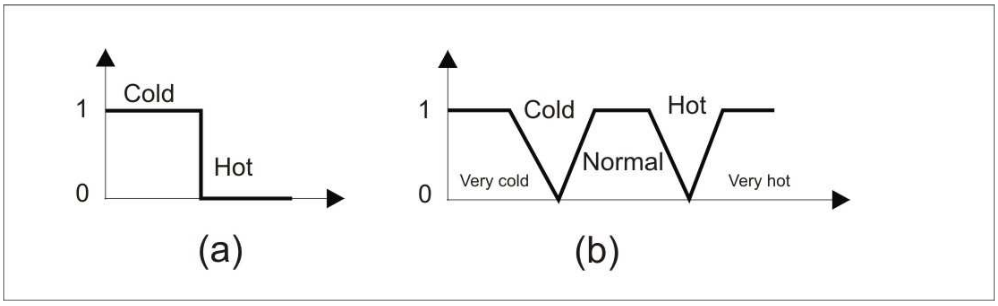


Figure 1.1 Crisp set and Fuzzy set a) Cold – hot crisp set (b) Very cold – cold – normal – hot – very hot fuzzy set

Consumers want to be able to reach their products as wireless. It can be possible Radio frequency (Rf) communications. Rf transmitters and receivers is used in security systems, temperature control systems, car park systems, identification systems by people. Users want to communicate their product from distance. So pruducts that are in all sectors is being update by producers and designers.

RFID (Radio frequency identification) is one of the most important developments in recents year. Using RFID systems provide rapidity and security to producers and consumers. They can find their product in a lot of products from distance and truly.

Basic Rf systems consists of two structures. These are transmitters and receivers. Transmitter takes data from users or outsides. It codes the data by using definite code system. Then, it adds the data that is coded to carrying signal that has definite frequency to communicate. Finally, it sends the data to receiver by antenna. Datas that is sent to receiver consists of identification knowledge, data that is taken outside and coded by transmitter and control data that is consicuited from data. Basic transmitter scheme is shown at Figure 1.2.

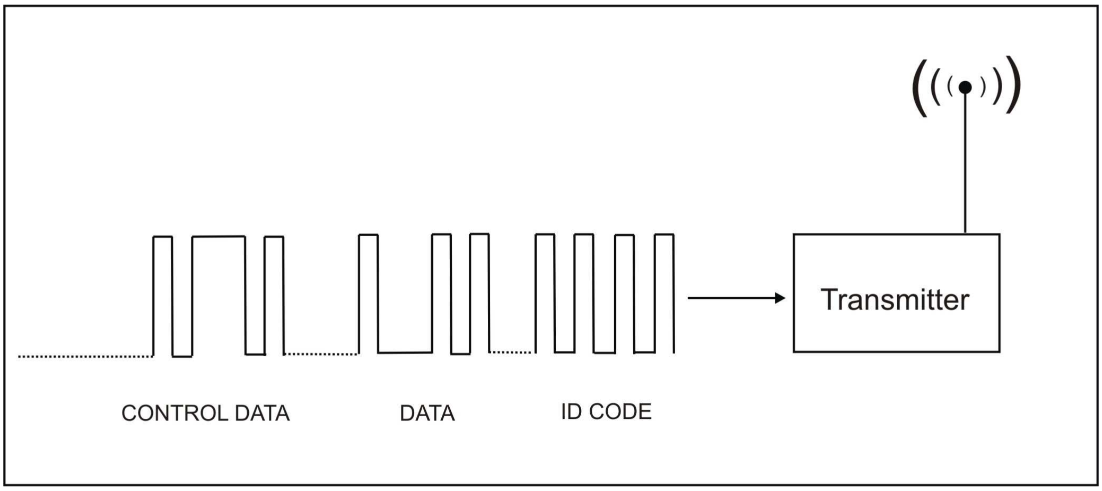


Figure 1.2 Basic transmitter scheme

Receiver anttenna takes signals that has definite frequency from outside. When it receives a signal, it fitler the signal and seperates carrying signal and data that is coded. Firstly, it searches identification data. When it finds the data, compeares with self identification data. If they are not same, it does not make any process. If they are same, it begins to decode data that takes from transmitter. It decodes all data and consicuites security data from decoded data. It compares security data that is taken from outside and control data that is consicuited in receiver. If they are not same, receiver does not make anything and wait new data. If they are same, it processes data that is decoded. Data that is taken from transmitter can consist of only knowledge or process knowledge or both of them. Basic reciver scheme is shown at Figure 1.3.

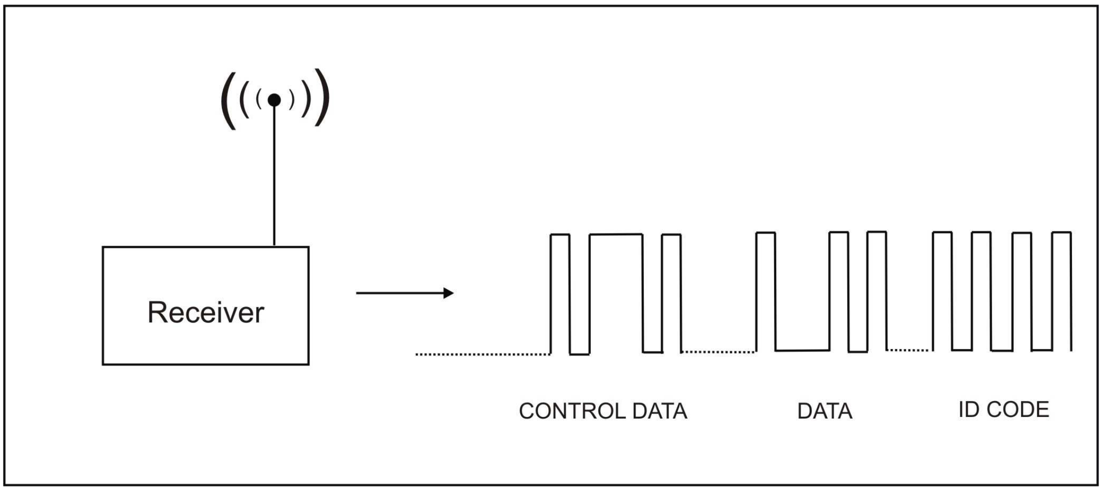


Figure 1.3 Basic receiver scheme

In this thesis gives information about elecronic system design that provides power savihg and runs by using Fuzzy logic and RF communication. The system consists of two main card, one transmitter module an done receiver module. The system takes from outside temperature data and inside temperature data. It compares these two datas and make a process on data by using Fuzzylogic. The end of the process, the system gives out optimum result. Since this result, the sytem controls component that controls product that consumes power. So system controls power consumption and saves energy.

The rest of the thesis is organized as follows. Fuzzy logic basics are presented in Chapter 2. Overview of triac control and its triggering methods are introduced in Chapter 3. Temperature control and sort of control are introduced in Chapter 4. Radio frequency and communication principles are explained in Chapter 5. The system application and working are explained in Chapter 6. Finally, conclusion and future plans for the improvement of the system are discussed in Chapter 7.

CHAPTER TWO
FUZZY LOGIC BASICS

2.1 Fuzzy Sets and Crisp Sets

The very basic Notion of fuzzy systems is a fuzzy (sub)set. In classical mathematics we are familiar with what we call crisp sets. For example, the possible interferometric coherence g values are the set X of all real numbers between 0 and 1. From this set X a subset A can be defined, (e.g.all values $0 \le g \le 0.2$). The characteristic function of A, (i.e. this function assigns a number 1 or 0 to each element in X, depending on whether the element is in the subset A or not) is shown in Figure 2.1. The elements which have been assigned the number 1 can be interpreted as the elements that are in the set A and the elements which have assigned the number 0 as the elements that are not in the set A. (Zadeh, 1965).

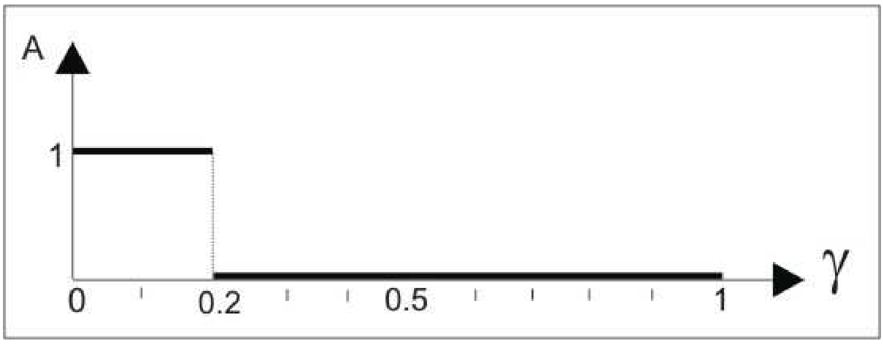


Figure 2.1 Characteristic function of a crisp set

This concept is sufficient for many areas of applications, but it can easily be seen, that it lacks in flexibility for some applications like classification of remotely sensed data analysis. Since g starts at 0, the lower range of this set ought to be clear. The upper range, on the other hand, is rather hard to define. As a first attempt, wes et the upper range to 0.2. Therefore we get B as a crisp interval B = [0,0.2]. But this means that a g value of 0.20 is low but a g value of 0.21 not. Obviously, this is a structural problem, for if we moved the upper boundary of the range from g = 0.20 to an arbitrary point we can pose the same question. A more natural way to construct the set B would be to relax the strict separation between low and not low.

This can be done by allowing not only the (crisp) decision Yes/No, but more fiexible rules like ”fairlylow”. A fuzzy set allows us to define such a notion. The aim is to use fuzzy sets in order to make computers more intelligent, therefore, the idea above has to be coded more formally. In the example, all the elements were coded with 0 or 1. A straight way to generalize this concept, is to allow more values between 0 and 1. Infact, infinitely many alternatives can be allowed between the boundaries 0 and 1, namely the unit interval I=[0,1]. The interpretation of the numbers, now assigned to all elements is much more difficult. Of course, again the number 1 assigned to an element means, that the element is in the set B and 0 means that the element is definitely not in the set B. All other values mean a gradual membership to the set B. This is shown in Figure 2.2. The membership function is a graphical representation of the magnitude of participation of each input. The rules use the input membership values as weighting factors to determine their infiluence on the fuzzy output sets of the final output conclusion. The membership function, operating in this case on the fuzzy set of g, returns a value between 0.0 and 1.0. For example, g of 0.3 has a membership of 0.5 to the set low you can see in Figure 2.2. It is important to point out the distinction between fuzzy logic and probability. Both operate over the same numeric range, and have similar values: 0.0 Representing False (or non-membership), and 1.0 representing True (or full-membership). However, there is a distinction to be made between the two statements: The probabilistic approach yields the natural-language statement, ”There is an 50% chance that g is low,” while the fuzzy terminology corresponds to ”g’s degree of membership within the set of low is 0.50.” The semantic difference is significant: the firrst view supposes that g is or is not low; it is just that we only have an 50% chance of knowing which set it is in. By contrast, fuzzy terminology supposes that g is ”more or less” low, or in some other term corresponding to the value of 0.50. (Zadeh, 1965 – Mandini & Gaines, 1981 – Klir & Yuan, 1996 – Bojadziev, 1996).

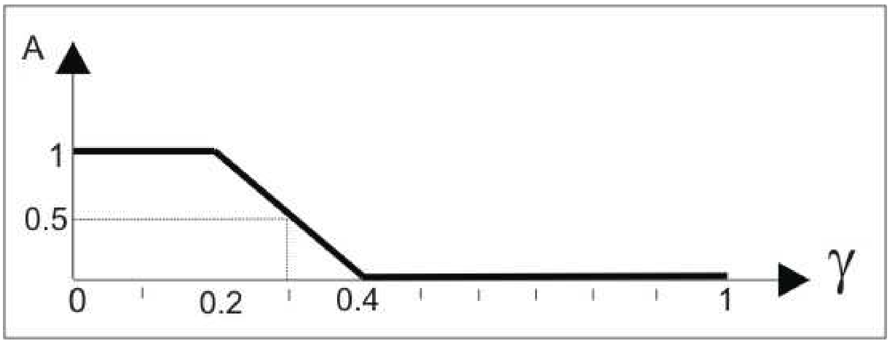


Figure 2.2 Characteristic Function of a Fuzzy set

2.1.1 Operatıon of Fuzzy Sets

We can introduce basic operations on fuzzy sets. Similar to the operations on crisp sets we also want to intersect, unify and negate fuzzy sets. It is suggested the minimum operator for the intersection and the maximum operator for the union of two fuzzy sets. (Zadeh, 1965 – Mandini & Gaines, 1981 – Klir & Yuan, 1996 – Ross, 2004). It can be shown that these operators coincide with the crisp unification, and intersection if we only consider the membership degrees 0 and 1. For example, if A is a fuzzy interval between 5 and 8 and B be a fuzzy number about 4 as shown in the Figure 2.3.

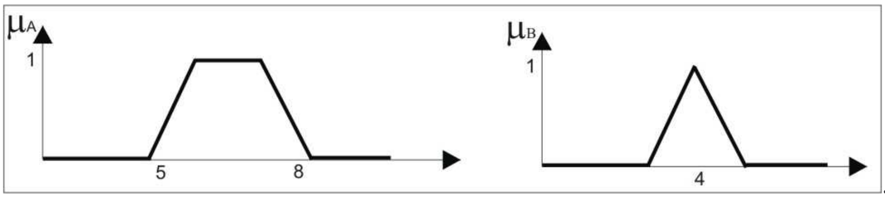


Figure 2.3 Example fuzzy set

In this case, the fuzzy set between 5 and 8 AND about 4 is shown in Figure 2.4.

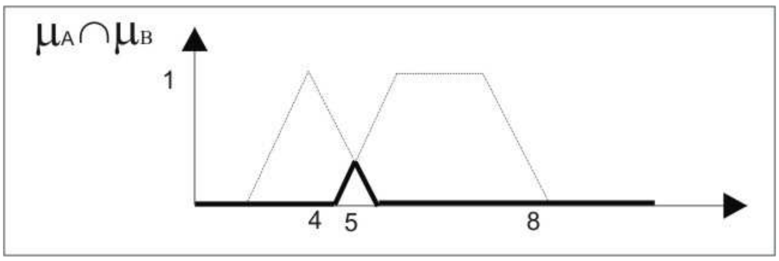


Figure 2.4 Example fuzzy AND

The fuzzy set between 5 and 8 OR about 4 is shown in Figure 2.5.

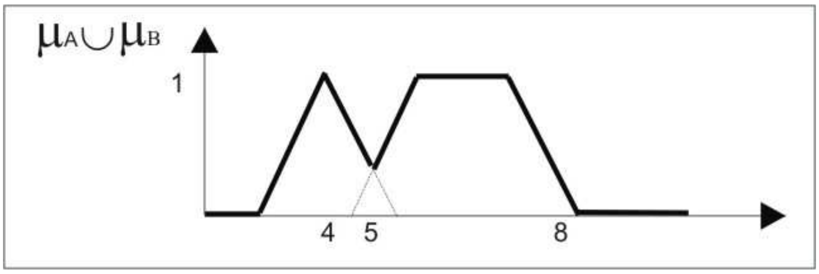


Figure 2.5 Example fuzzy OR

The NEGATION of the fuzzy set A is shown in Figure 2.6.

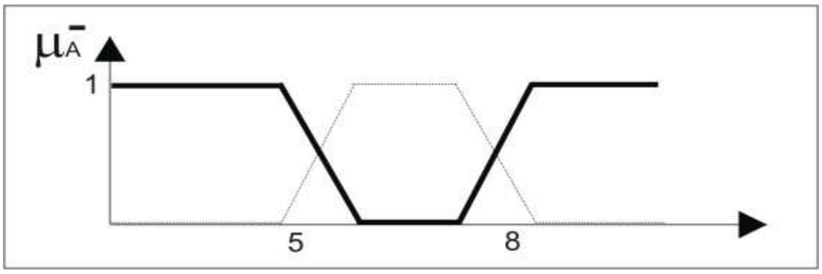


Figure 2.6 Example fuzzy NEGATION

2.1.2 Fuzzy Classification

Fuzzy classifiers are one application of fuzzy theory. (Zimmermann, 1987 – Kruse, Gebhardt & Klawon, 1994). Expert knowledge is used and can be expressed in a very natural way using linguistic variables, which are described by fuzzy sets Now the expert knowledge for this variables can be formulated as a rules like

IF feature A low AND feature B medium AND feature C medium AND feature D medium THEN Class = class4.

The rules can be combined in a table calls rule base.

Table 1.1 Example for a fuzzy rule base

R#	Feature A	Feature B	Feature C	Feature D	Class
1	Low	Medium	Medium	Medium	Class1
2	Medium	High	Medium	Low	Class2
3	Low	High	Medium	High	Class3
4	Low	High	Medium	High	Class1
5	Medium	Medium	Medium	Medium	Class4
..	…	…	…	…	…
N:	Low	High	Medium	Low	unknown

Linguistic rules describing the control system consist of two parts; an antecedent block (between the IF and THEN) and a consequent block (following THEN). Depending on the system, it may not be necessary to evaluate every possible input combination. (Mandini & Gaines, 1981 – Klir & Yuan, 1996 – Bojadziev, 1996 – Ross 2004). Since some may rarely or never occur. By making this type of evaluation, usually done by an experienced operator, fewer rules can be evaluated, thus simplifying the processing logic and perhaps even improving the fuzzy logic system performance. Linguistic variables are shown in Figure 2.7.

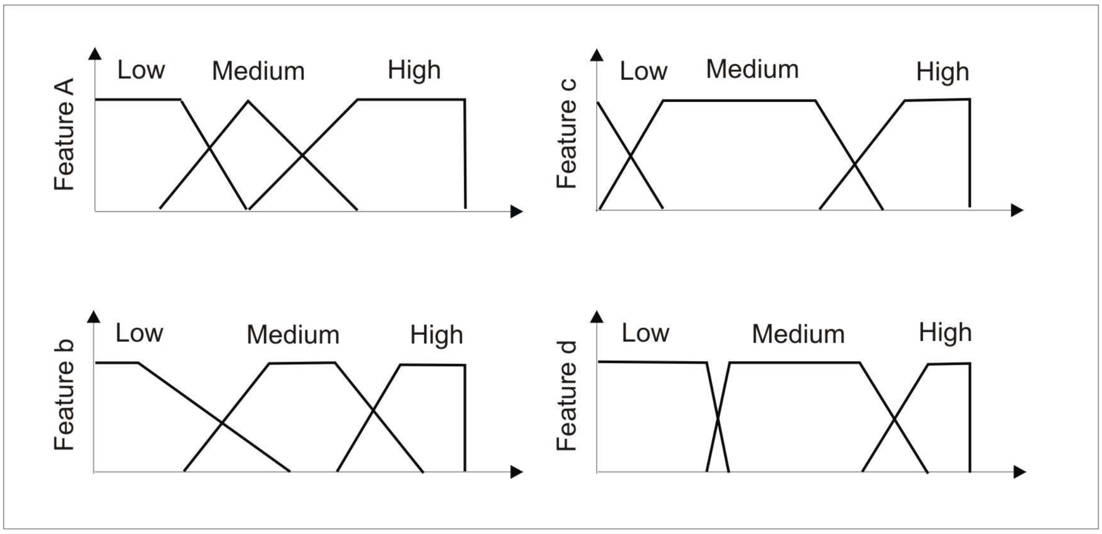


Figure 2.7 Linguistic variables

The fuzzy outputs for all rules are finally aggregated to one fuzzy set. To obtain a crisp decision from this fuzzy output, we have to defuzzify the fuzzy set, or the set of singletons. Therefore, we have to choose one representative value as the final output. There are several heuristic methods (defuzzification methods), one of them is e.g. to take the center of gravity of the fuzzy set as shown in Figure 2.8, which is widely used for fuzzy sets. For the discrete case with singletons usually the maximum method is used where the point with the maximum singleton is chosen. (Zadeh, 1965 – Mandini & Gaines, 1981 – Kruse, Gebhardt & Klawon, 1994).

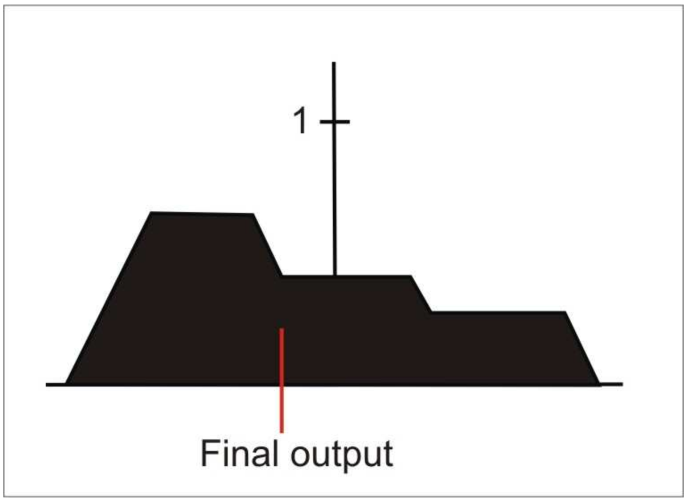


Figure 2.8 Defuzzification using the center of gravity approach

2.2 Structure of A Fuzzy Controller

There are specific components characteristic of a fuzzy controller to support a design procedure. (Zadeh, 1965 – Mandini & Gaines, 1981). In the block diagramin Figure 2.9, the controller is between a pre-processing block and a post-processing block.

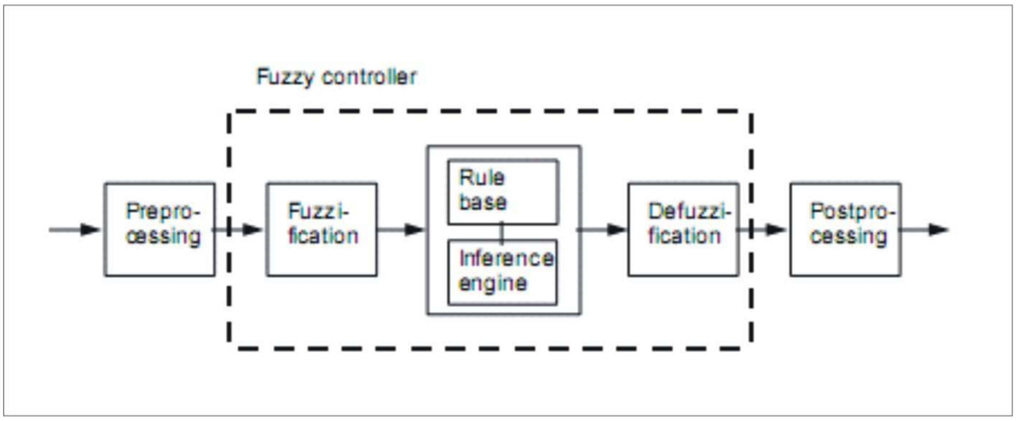


Figure 2.9 Blocks of fuzzy controller

2.2.1 Preprocessing

The inputs are most often hard or crisp measurements from some measuring equipment, rather than linguistic. (Mandini & Gaines, 1981 – Ross, 2004). A preprocessor, the first block in Figure 2.9, conditions the measurements before they enter the controller. Examples of preprocessing are:

- Quantisation in connection with sampling or rounding to integers
- Normalisation or scaling on to a particular, standard range
- Filtering in order to remove noise
- Averaging to obtain long term or short term tendencies
- A combination of several measurements to obtain key indicators
- Differentiation and integration or their discrete equivalences

A quantiser is necessary to convert the incoming values in order to find the best level in a discrete universe .Assume, for instance, that the variable error has the value 4.5, but the universe is u = (-5, -4, ….., 0, ….,+4, +5) .The quantiser rounds to 5 to fit it to the nearest level. Quantisation is a means to reduce data, but if the quantisationis too coarse the controller may oscillate around the reference or even become unstable. When the input to the controller is error, the control strategy is a static mapping between input and control signal. A dynamic controller would have additional inputs, for example derivatives, integrals, or previous values of measurements backwards in time. These are created in the preprocessor thus making the controller multidimensional, which requires many rules and makes it more difficult to design. The preprocessor then passes the data on to the controller.

2.2.2 Fuzzification

The first block inside the controller is fuzzification, which converts eachpiece of input data to degrees of membership by a lookup in one or several membership functions. The fuzzification block thus matches the input data with the conditions of the rules to determine how well the condition of each rule matches that particular input instance. There is a degree of membership for each linguistic term that applies to that input variable. (Zadeh, 1965 – Mandini & Gaines, 1981 – Klir & Yuan, 1996 – Ross, 2004).

2.2.2.1 Rule Base

The rules may use several variables both in the condition andt he conclusion of the rules. The controllers can therefore be applied to both multi-input-multi output (MIMO) problems and single-input-single output (SISO) problems. The typical SISO problem is to regulate a control signal based on an error signal. The controller may actually need both the error, the change in error, and the accumulated error as inputs,but we will call it single-loop control, because in principle all three are formed from the error measurement. To simplify this section assumes that the control objective is to regulate some process output around a prescribed set point or reference.

2.2.2.1.1 Rule Formats. Basically a linguistic controller contains rules in the if-then format, but they can be presented in different formats. In many systems, the rules are presented to the end-user in a format similar to the one below,

- If error is Neg and change in error is Neg then output is NB
- If error is Neg and change in error is Zero then output is NM

- If error is Neg and change in error is Pos then output is Zero
- If error is Zero and change in error is Neg then output is NM
- If error is Zero and change in error is Zero then output is Zero
- If error is Zero and change in error is Pos then output is PM
- If error is Pos and change in error is Neg then output is Zero
- If error is Pos and change in error is Zero then output is PM
- If error is Pos and change in error is Pos then output is PB

The names Zero, Pos, Neg are labels of fuzzy sets as well as NB, NM, PB and PM (negative big, negative medium, positive big, and positive medium respectively). The same set of rules could be presented in a relational format, a more compact representation. It is shown at Table 2.1.

Table 2.1. Relational format

Error	Change in error	Output
Neg	Pos	Zero
Neg	Zero	NM
Neg	Neg	NB
Zero	Pos	PM
Zero	Zero	Zero
Zero	Neg	NM
Pos	Pos	NB
Pos	Zero	PM
Pos	Neg	Zero

The top row is the heading, with the names of the variables. It is understood that the two left most columns are inputs, the right most is the output, and each ro w represents a rule. This format is perhaps beter suited for an experienced user who wants to get an overview of the rule base quickly. The relational format is certainly suited for storing in a relational database. It should be emphasised, though, that the relational format implicitly assumes that the connective between the inputs is always logical and or logical or for that matter as long as it is the same operation for all rules and not a mixture of connectives. Incidentally, a fuzzy rule with an or combination of terms can be converted into an equivalent and combination of terms using laws of logic. A third format is the tabular linguistic format. It is shown at Table 2.2.

Table 2.2 Tabular linguistic format

	Change in error			
Error		Neg	Zero	Pos
	Neg	NB	NM	Zero
	Zero	NM	Zero	PM
	Pos	Zero	PM	PB

This is even more compact. The input variables are laid out along the axes, and the output variable is inside the table. In case the table has an empty cell, it is an indication of a missing rule, and this format is useful for checking completeness. When the input variables are error and change in error, as they are here, that format is also called a linguistic phase plane.

Lastly, a graphical format which shows the fuzzy membership curves is also possible. This graphical user-interface can display the inference process beter than the other formats, but takes more space on a monitor.

2.2.2.1.2 Connectives. In mathematics, sentences are connected with the words “and”, “or”, “if-then”(or implies),and “if and only if”,o modifications with the word “not”. These five are called connectives. It also makes a difference how the connectives are implemented. The most prominent is probably multiplication for fuzzy “and” instead o fminimum. So far most of the examples have only contained “and” operations.

The connectives “and” and “or” are always defined in pairs, for example,

A and B = min(A,B) Minimum

A or B = max(A,B) Maximum

2.2.2.1.3 Modifiers. A linguistic modifier, is an operation that modifies the meaning of a term. For example, in the sentence ‘‘very close to 0’’,the word very modifies “close to 0” which is a fuzzy set. A modifier is thus an operationon a fuzzy set. The modifier “very” can be defined as squaring the subsequent membership function, that is

$$\text{very } a = a^2$$

Some examples of other modifiers are

$$\text{Extremly } a = a^3$$

$$\text{Slightly } a = a^{1/2}$$

A whole family of modifiers is generated by a^p where “p” is any power between zero and infinity.

2.2.2.1.4 Universes. Elements of a fuzzy set are taken from a universe of discourse or just universe. The universe contains all elements that can come into consideration. Before designing the membership functions it is necessary to consider the universes for the inputs and outputs.

Another consideration is whether the input membership functions shouldbe continuous or discrete. A continuous membership function is defined on a continuous universe by means of parameters. A discrete membership function is defined in terms of a vector with a finite number of elements. In the latter case it is necessary to specify the range of the universe and the value at each point. The choice between fine and coarse resolution is a trade off between accuracy, speed and space demands. The quantiser takes time to execute, and if this time is too precious, continuous membership functions will make the quantiser obsolete.

2.2.2.1.5 Membership functions. Every element in the universe of discourse is a member of a fuzzy set to some grade, maybe even zero. The grade of membership for all its members describes a fuzzy set, such as “Neg”. In fuzzy sets elements are assigned a grade of membership, such that the transition from membership to non-membership is gradual rather than abrupt.

The set of elements that have a non-zeromembership is called the support of the fuzzy set. The function that ties a number to each element "x" of the universe is called the membership function μ(x) Membership functions can be flat on the top, piece-wise linear and triangle shaped, rectangular, or ramps with horizontal shoulders. Figure 2.10 shows some typical shapes of membership functions.

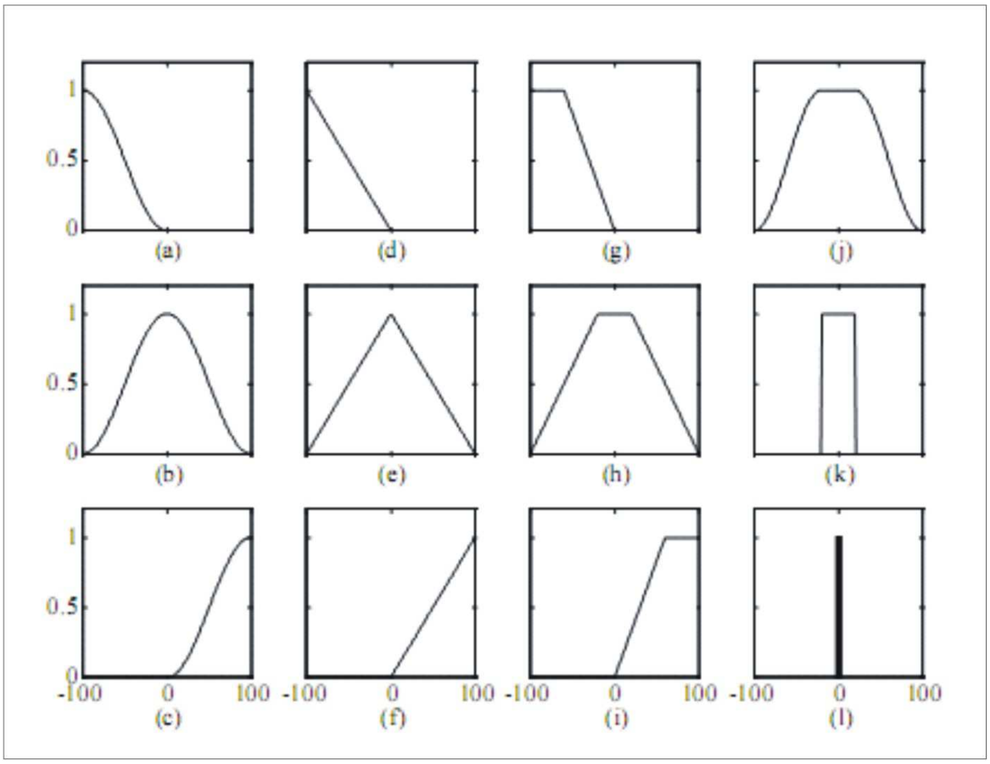


Figure 1.10 Examples of membership functions. Read from top to bottom, left to right: (a) s function, (b) π - function, (c) z - function, (d-f) triangular versions, (g-i) trapezoidal versions, (j) flat function,(k) rectangle, (l) singleton.

Strictly speaking, a fuzzy set A is a collection of ordered pairs

$$A = \{ x, \mu(x) \}$$

Item x belongs to the universe and μ(x), is its grade of membership in A. A single pair{ x, μ(x) }, is a fuzzy singleton ;singleton outputs means replacing the fuzzy sets in the conclusion by numbers (scalars). For example,

- If error is Pos then output is 10 volts
- If error is Zero then output is 0 volts
- If error is Neg then output is -10 volts

There are at least three advantages to this:

- The computations are simpler;
- It is possible to drive the control signal to its extreme values; and
- it may actually be a more intuitive way to write rules.

The scalar can be a fuzzy set with the singleton placed in a proper position. For example 10 volts, would be equivalent to the fuzzy set (0, 0, 0, 0,1) defined on the universe (-10, -5, 0, 5, 10) volts

2.2.2.2 Defuzzification

The resulting fuzzy set must be converted to a number that can be sent to the process as a control signal. This operation is called deffuzication, and vertical dividing line becomes the control signal. The resulting fuzzy set is thus defuzzified into a crisp control signal. There are several defuzzification methods. (Zadeh, 1965 – Mandini & Gaines, 1981 – Klir & Yuan, 1996 – Ross, 2004).

2.2.2.2.1 Center of Gravity (COG). The crisp output value x is the abscissa under the centre of gravity of the fuzzy set,

$$U = \frac{\sum_i \mu(Xi)Xi}{\sum_i \mu(Xi)}$$

Here Xi is a running point in a discrete universe, and $\mu(Xi)$, is its membership value in the membership function. The expression can be interpreted as the weighted average of the elements in the support set. For the continuous case, replace the summations by integrals. It is a much used method although its computational complexity is relatively high. This method is also called centroid of area.

2.2.2.2.2 Center of Gravity for singleton (COGS). If the membership functions of the conclusions are singletons. The output value is,

$$U = \frac{\sum_i \mu(Si)Si}{\sum_i \mu(Si)}$$

Here Si is the position of singleton i in the universe, and $\mu(Si)$ is equal to the firing strength αi of rule i. This method has a relatively good computational complexity, and U is diffrentable with respect to the singletons Si which is useful in neuro fuzzy systems.

2.2.2.2.3 Bisector of area (BOA). This method picks the abscissa of the vertical line that divides the are a under the curve in two equal halves. In the continuous case,

$$u = \left\{ \chi \,\middle|\, \int_{Min}^{\chi} \mu(\chi)d\chi = \int_{\chi}^{\max} \mu(\chi)d\chi \right\}$$

Here X is the running point in the universe, $\mu(\chi)$, is its membership, Min is the left most value of the universe, and Max is the right most value. Its computational complexity is relatively high, and it can be ambiguous. For example, if the fuzzy set consists of two singletons any point between the two would divide the area in two halves; consequently it is safer to say that in the discrete case, BOA is not defined.

2.2.2.2.4 Mean of maxima (MOM). An intuitive approach is to choose the point with the strongest possibility, i.e. maximal membership. It may happen, though, that several such points exist, and a common practice is to take the mean of maxima (MOM). This method disregards the shape of the fuzzy set, but the computational complexity is relatively good.

2.2.2.2.5 Leftmost maximum (LM) and rightmost maximum (RM). Another possibility is to choose the leftmost maximum(LM), or the rightmost maximum(RM). In the case of a robot, for instance, it must choose between left or right to avoid an obstacle in front of it. The defuzzifier must then choose one or the other, not something in between. These methods are in different to the shape of the fuzzyset, but the computational complexity is relatively small.

2.2.2.2 Postprocessing

Outputs caling is also relevant. In case the output is defined on a Standard universe this must be scaled to engineering units for instance, volts, meters, or tons per hour. An example is the scaling from the Standard universe [-1,1] to the physical units [-10,10] volts. The postprocessing block often contains an output gain that can be tuned, and sometimes also an integral. (Mandini & Gaines, 1981 – Klir & Yuan, 1996 – Ross, 2004).

CHAPTER THREE
TRIAC CONTROL

3.1 Triac Control Basics

A Triac is the optimum device for solid state control of Single Phase AC loads at low frequency, (i.e.mains.). Control can take the form of simple on-off switching as required for basic low cost equipment, such as thermostats or any simple loads where only full power must be applied. (Bradley, 1995 – Marston, 1997).

It can also take the form of variable power control by the use of "phase control", where the AC sinewave is chopped by delaying the Triac trigger in each half cycle of the mains cycle. (Maloney 1986). The basic Voltage / Current relationship for a resistive Load is shown in Figure 3.1.

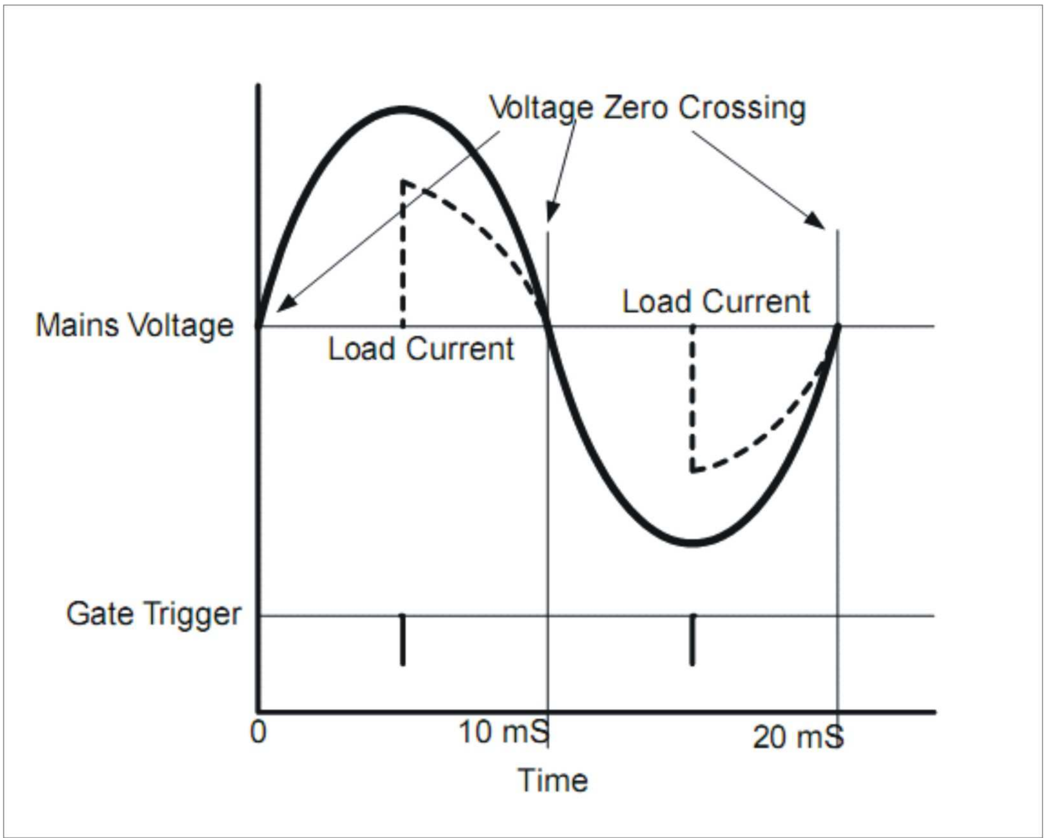


Figure 3.1 Basic Current and Voltage Relationship

With a phase control system, the Triac is controlled during each period of the mains voltage. The power transferred to the load is proportional to the Current Flow. This makes this approach suitable to drive an inductive load (i.e. Universal or Single phase motors). (Bradley, 1995 – Marston, 1997).

Figure 3.2 shows the relation between the Phase Angle "a" and the current flow angle "g", for an Inductive Load where the load Current lags the Voltage by 90.

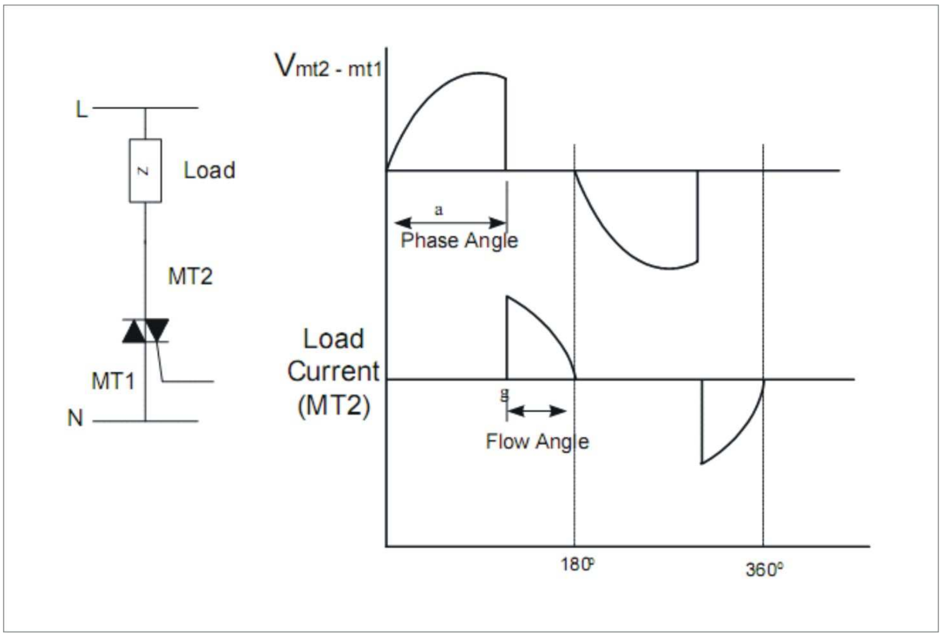


Figure 3.2 Phase Angle and Load Current Relationships

Increasing or decreasing the phase angle or more specifically the time delay during each mains cycle controls the motor speed. It is important therefore that the Phase Angle (time delay) is synchronised with the mains cycle and it needs to be kept constant during both half cycles. This means that, if the mains voltage frequency is 50 Hz the phase angle may be changed every 20 mS. The Triac will turn off ("commutate"), when the load current reaches zero, thus the need to provide a phase angle trigger the in both halves of the Mains cycle. (Williams, 1987 – Bradley, 1995 – Marston, 1997).

The usual method of synchronising to the Mains cycle is to detect the Voltage Zero Crossing points. This is normally done for either the Positive or both Positive and Negative zero crossing points. Current zero crossing detection is normally used where a continuous supply is applied to the Load and the Triac is triggered at each current zero crossing point. (Maloney, 1986 – Williams, 1987 – Bradley, 1995).

The Microcontroller can use the Voltage zero crossing points as a reference to calculate the appropriate Phase Angle (Time delay) requirements. Some allowance needs to be made for Inductive loads as current and voltage are not in phase. Ideally the trigger should be made at a time after the Load current has reached zero in order to reduce load current discontinuity and reduce Electromagnetic Interference (EMI). Figure 3.3 shows a typical timing relationship to the 50 Hz mains cycle

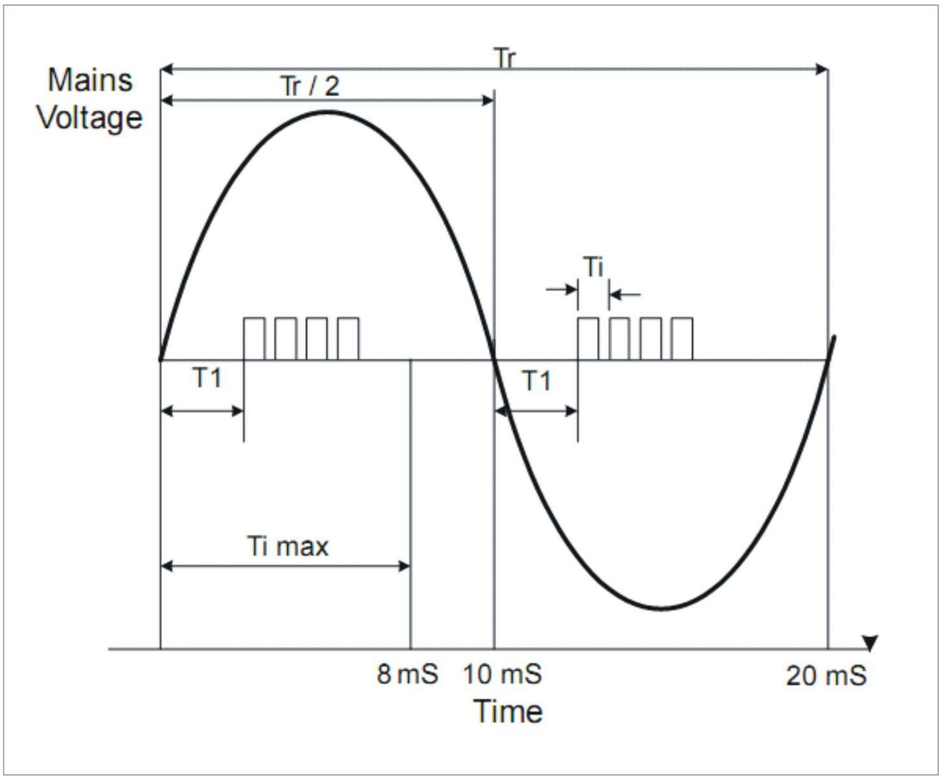


Figure 3.3 Basic Timing Relationships

- Tr is the Full Mains cycle time. (Based on 50 Hz)
- Tr / 2 is the Half cycle time. (Based on 50 Hz)
- T1 is the Phase angle delay
- Ti max is the maximum Phase Angle delay
- Ti is the Triac Gate trigger pulse period

3.2 Triac Trigering Basics

Triac's are manufactured in many different forms that include

- Three and Four Quadrant
- Standard and Snubberless
- Low Sensitivity

Three-quadrant Triac's are considered in this Application for their improved immunity to commutation failure or loss of control and false triggering. This is because a three-quadrant Triac does not trigger in th the 4 quadrant that you can see in Figure 3.4, so that the gate drive circuit cannot falsely trigger the Triac. This is not important as the vast majority of IC drive circuits, are designed to sink current. This certainly holds true for many Microcontrollers, which are capable of sinking more current than they can source. In these cases Gate triggering is usually performed in Quadrants 2 and 3 (MT2+, G- and MT2-, G-), while triggering is not achieved in quadrant 1, as there is insufficient current available to trigger the Triac and the Gate Voltage is held in the inactive state. (Williams, 1987 – Bradley, 1995).

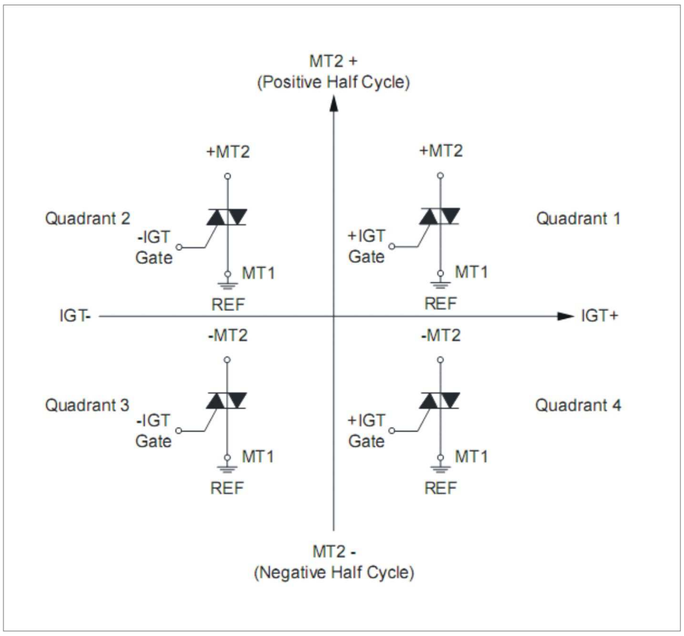


Figure 3.4 Triac Quadrant Definitions

Triac's that provide Low Gate Sensitivity are essential for applications that are driven directly from a Microcontroller, as they require low Gate trigger currents. Many Triac types are available on the market with gate trigger currents ranging from 5mA to 50mA. It is necessary to ensure that the Microcontroller supplies enough gate current for the Triac to exceed the "Latching" current through the Load. Once this has been reached the Gate current can be removed and the Triac will continue to conduct until the load current reaches zero (i.e. the Triac will commutate). Typically a number of Gate Trigger pulses are employed over a short period of time, rather than a continuous Gate Current, to ensure the latching current level is reached.

Historically a Triac that required low Gate trigger current also had a low Rate of Change of Voltage (dv/dt). In these cases a R/C "Snubber" network was usually required to ensure that the Triac and Loadcan be turned off (Especially for Inductive Loads). Also in some cases a series inductor with the Triac / Load was also needed, adding further complexity and component cost.

Triacs are generally identified as:

- Standard (May require a Snubber circuit)
- Snubberless (Do not require a Snubber circuit)

Many modern Triac's however now provide a sufficiently high dv/dt specifications such that they do not require a "Snubber" or series inductor for inductive loads. (Williams, 1987 – Bradley, 1995 – Marston, 1997).

3.3 Optocouplers for triggering triac

The non-zero-crossing optocoupler will activate at any phase difference between the outputs when the input is activated. That means if you activate the optocoupler while the voltage difference is at its maximum, it will activate, causing a large voltage and current changes (which can cause interference if not filtered properly). Inductive devices, like relays and motors, may not like this. Non-zero crossing optocouplers are useful fi you are building for example dimmers where you control the triac firing angle. MOC3010 and MOC3020 are typical non-zero-crossing optocouplers. (Williams, 1987 – Marston, 1999).

The zero-crossing optocoupler will not activate until the voltage differential between the outputs is zero. Even if you turn on the optocoupler while the voltage is at its greatest difference, it will not activate the output until the voltage differential is zero, therefore avoiding rapid large voltage changes. Commercial general purpose semiconductor relays typically use zero-crossing optocouplers. MOC3031 and MOC3041 are typical zero-crossing optocouplers.

3.3.1 Simplest Circuit

The simplest way to get the right curretn going through the LED in the optocoupler is to use current limiting resistor calculated from the control voltage and the current the optocoupler needs. The formula for current limiting resistor resistance (in ohms) is:

R1 = 1000 * (Uinput - 1.3V) / controlcurrent

In the formula above the 1.3 V comes from the voltage drop over typical LED used in optocouplers. The circuit for current limiting resistor is shown at Figure 3.5.

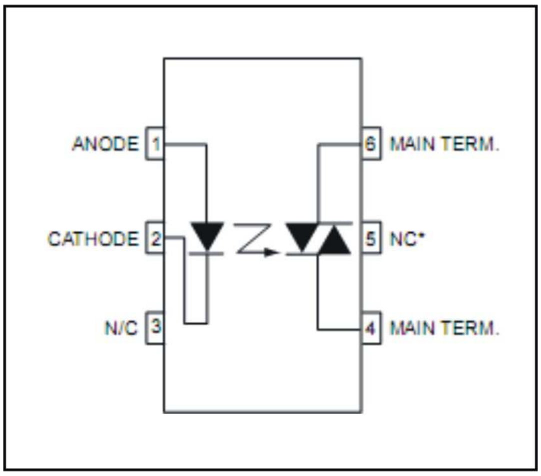


Figure 3.5 Simplest circuit

Single resistor current limiting circuit is very simple and useful when you know the voltage you are using for controlling. The problem is that if the voltage changes much, the LED will get too little or too much current. (Williams, 1987 – Marston, 1999).

The circuit in Figure 3.6 is the basic circuit for on - off power control. With a continuous forward current through the LED, the detector of the zero-crossing optocoupler switches to the conducting state only when the applied ac voltage passes through a point near zero. Phase control applications, such as controlling the speed of a motor or brilliance of a lamp, require triggering at points along the ac voltage wave. This necessitates a random phase triac driver optocoupler. (Williams, 1987 – Marston, 1999).

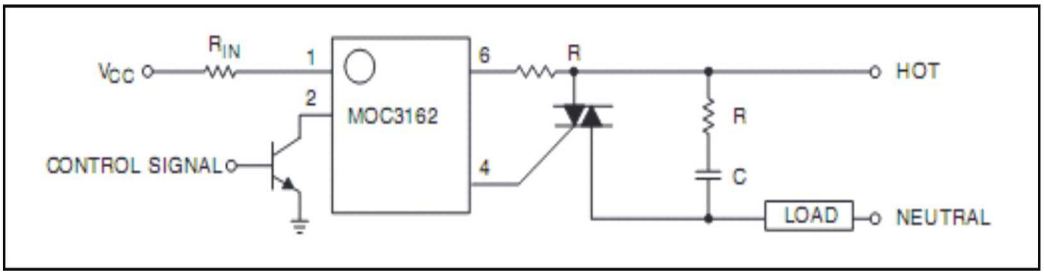


Figure 3.6 Basic circuit for on-off power control

CHAPTER FOUR
TEMRERATURE CONTROL

4.1 Control Loops Explained

Whatever the process or the parameter (temperature, flow, speed for example), the principles of control are similar. Input and output signals are specified as appropriate to the application, usually analog (e.g. thermocouples signal input, solid state output power control) but these may be digital. (Webb, 1964 – Childs, 2001).

This chapter assumes temperature control with either a thermocouple or platinum resistance thermometer input and a proportional control output. Control of a process is achieved by means of a closed loop circuit is shown Figure 4.1

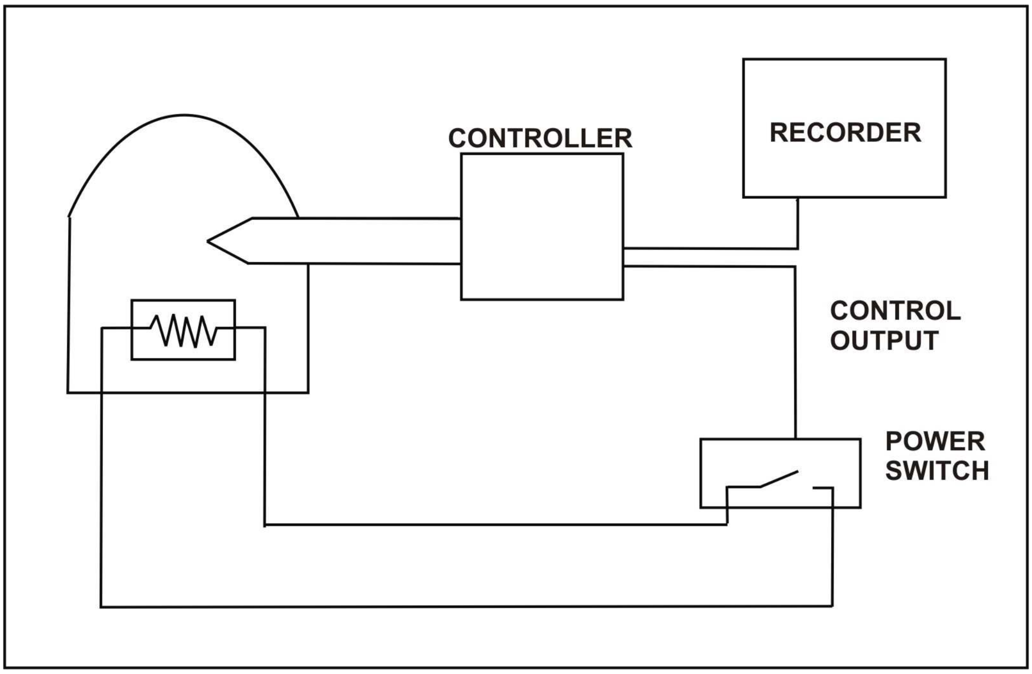


Figure 4.1 Closed Loop Circuit

4.2 PID Explained

Only very control of temperature can be achieved by causing heater power to be simply switched on and off according to an under or over temperature condition respectively. Ultimately, the heater power will be regulated to achieve a desired system temperature but refinement can be employed to enhance the control accuracy. Such refinement is available in the form of proportional (P), integral (I), and derivative (D) functions applied to the control loop. These functions, referred to as control "terms" can be used in combination according to system requirements. The desired temperature is usually referred to as the set-point (SP). (Dwyer, 2006 – Knospe, 2006)

To achieve optimum temperature control whether using on-off, P, PD or PID techniques, ensure that:

- Adequate heater power is available (ideally control will be achieved with 50% power applied!)
- The temperature sensor, be it thermocouple or PRT, is located within reasonable "thermal" distance of the heaters such that it will respond to changes in heater temperature but will be representative of the load temperature (the "thing" being heated).
- Adequate "thermal mass" in the system to minimise its sensitivity to varying load or ambient conditions.
- Good thermal transfer between heaters and load.
- The controller temperature range and sensor type are suitable – try to choose a range that results in a mid-scale set-point.

4.2.1 On-Off Control Function

Usually simplest and cheapest but control may be oscillatory. Best confined to alarm functions only or when "thermostatic" type control is all that is required, but this may be the most suitable means of control in some applications. Figure 4.2 show on-off control graphic. (Webb, 1964 – Harriot, 1964 – Patrick, 1997 – Anderson, 1998 – McMillian, 1999).

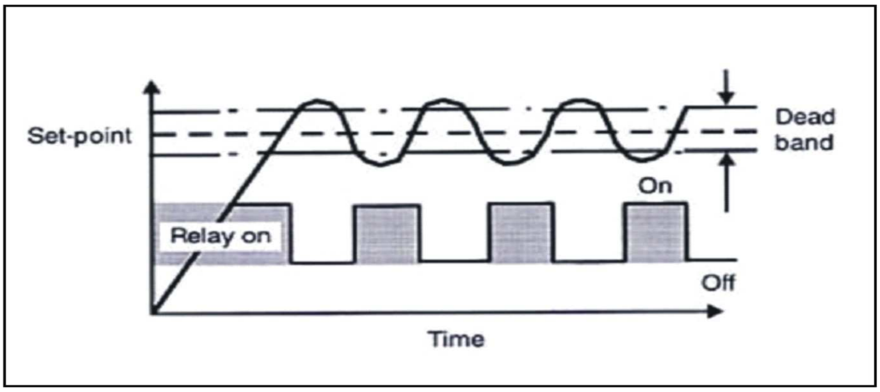


Figure 4.2 On-Off control graphic

4.2.2 Proportional Control Function

A form of anticipatory action which slows the temperature rise when approaching set-point. Variations are more smoothly corrected but an offset will occur (between set and achieved temperatures) as conditions very. Figure 4.3 show proportional control graphic. (Webb, 1964 – Harriot, 1964 – Patrick, 1997 – Anderson, 1998 – McMillian, 1999 – Dwyer, 2006 – Knospe, 2006).

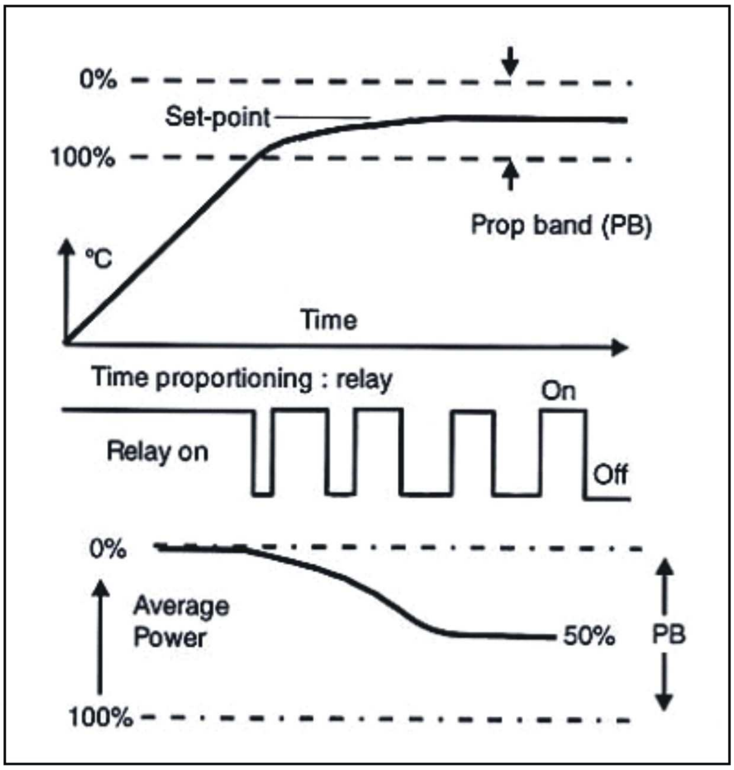


Figure 4.3 Proportional control graphic

Average heater power over a period of time is regulated and applied power is proportional to the error between sensor temperature and set-point (usually by time proportioning relay switching). The region over which power is thus varied is called the Proportional Band (PB) it is usually defined as a percentage of full scale.

Offset is the deviation of the sensor temperature from the desired value (set-point). This can be adjusted out manually by means of a potentiometer adjustment (Manual reset) or automatically (Integral Action). Offset is shown at Figure 4.4.

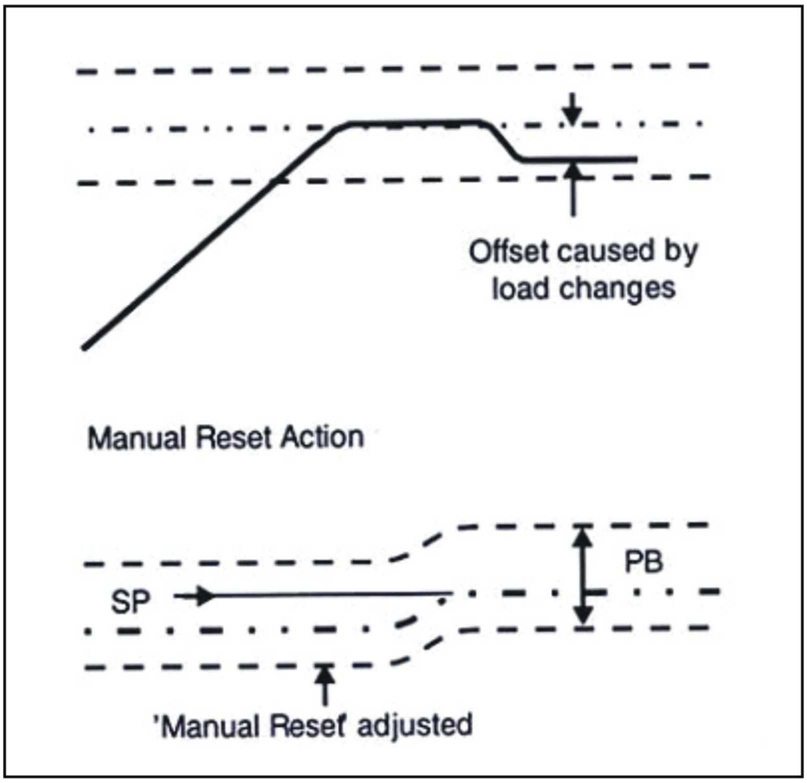


Figure 4.4 Offset

The proportional term, also called gain, must have a value greater than zero for the control loop to operate. The value of the proportional term is multiplied by the error (e) to generate the proportional contribution to the output :

$$\text{Output (P)} = Pe.$$

If proportional is acting alone, with no integral, there must always be an error or the output will go to zero. A great deal must be known about the load, sensor, and contrtoller to compute a proportional setting (P). Most often, the proportional setting is determined by trial and error. The proportional setting is part of the overall control loop gain, as well as the heater range and cooling power. The proportional setting will need to change if either of these change.

4.2.3 Proportional - Derivative Control Function

The Derivative term when combined with proportional action improves control by sensing changes and correcting for them quickly. The proportional is effectively intensified (its gain is increased) to achieve a quicker response. Figure 4.5 show proportional – derivative control graphic. (Webb, 1964 – Harriot, 1964 – Patrick, 1997 – Anderson, 1998 – McMillian, 1999 – Dwyer, 2006 – Knospe, 2006).

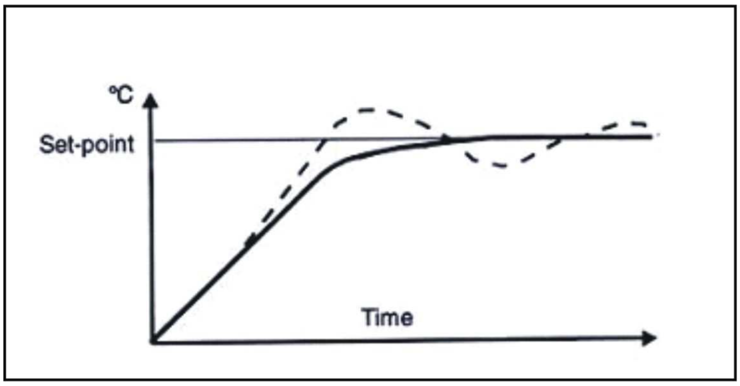


Figure 4.5 Proportional – Derivative control graphic

The derivative term, also called rate, acts on the change in error with time to make its contribution to the output :

$$\text{Output(D)} = \text{PD}\frac{de}{dt}$$

By reacting to a fast changing error signal, the deriative can work to boost the output when the setpoint changes quickly, reducing the time it takes for temperature to reach the setpoint. It can also see the error decreasing rapidly when the temperature nears the setpoint and reduce the output for less overshoot. The derivative term can be useful in fast changing systems, but it is often turned off during steady state control because it reacts too stongly to small disturbances or noise. The derivative setting (D) is related to the dominant time constant of the load.

4.2.4 Proportional – Integral - Derivative Control Function

Adding an integral term to PD control can provide automatic and continuous elimination of any offset. Integral action operates in the steady state condition by shifting the Proportional Band upscale or downscale until the system temperature and set-point coincide. (Webb, 1964 – Harriot, 1964 – Patrick, 1997 – Anderson, 1998 – McMillian, 1999 – Dwyer, 2006 – Knospe, 2006).

In the control loop, the integral term, also called reset, looks at error level time to built the integral contribution to the output :

$$\text{Output (I)} = \text{PI} \int (e)dt$$

By adding integral to the proportional contribution, the error that is necessary in a proportional-only system can be eliminated. When the error is at zero, controlling at the setpoint, the output is held constant by the integral controbution. The integral setting (I) is more predictable than the proportional setting. It is related to the dominant time constant of the load. Measuring this time constant allows a reasonable calculation of the integral setting.

4.2.5 Closed loop PID control

Closed loop PID control, often called feedback control, is the control mode most often assosiated with temperature controllers. In this mode, the controller attempts to keep the load at exactly the user entered set point, which can be entered in sensor units or temperature. To do this, it uses feedback from the control sensor to calculete and actively adjust the control (heater) output. The control algorithm used is called PID. (Dwyer, 2006 – Knospe, 2006).

The PID control equation has three variable terms: Proportional (P) ,integral (I) and derivative (D)

$$\text{Heater Output} = P\left[e + I\int(e)dt + D\frac{de}{dt}\right]$$

where the error (e) is defined as:

e = setpoint – Feedback Reading

Closed loop PID control is shown at Figure 4.6

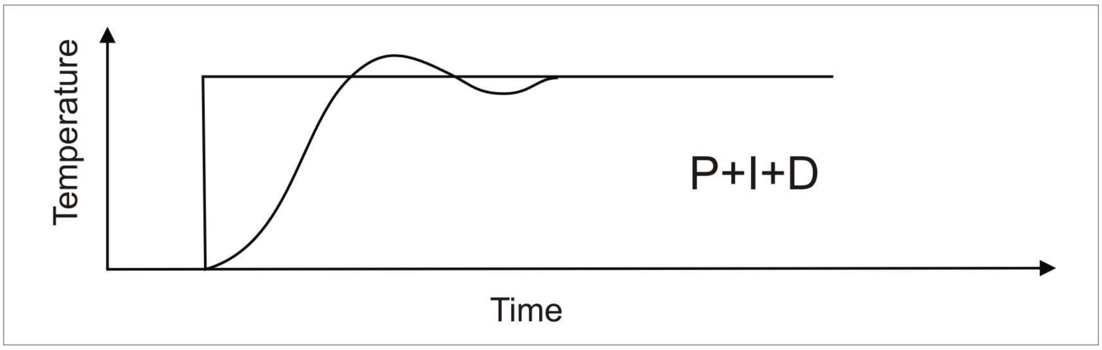


Figure 4.6 Closed loop PID control

4.2.6 Choosing P, PD or PID

Although superior control can be achieved in many cases with PID control action, values of the PID terms inappropriate to the application can cause problems.

If an adequately powered system with good thermal response exists and the best possible control accuracy is required, full PID control is recommended.

If somewhat less critical precision is demanded, the simpler PD action will suffice and will suit a board range of applications.

If simple control is all that is required, for instance to improve upon thermostatic switching, Proportional (P) or on-off action will suffice.

4.2.7 Fast Tune PID Control

All processes have some finite time delays and on-off control will result in start-up temperature overshoot as shown Figure 4.7. (Dwyer, 2006 – Knospe, 2006).

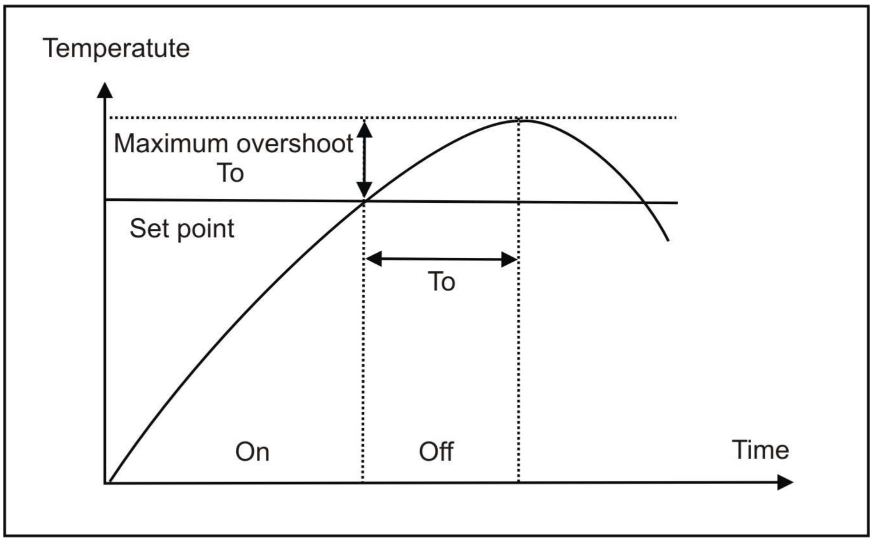


Figure 4.7 Start-up temperature overshoot

4.2.8 Auto Tune PID Control

Auto tune controllers utilise PID terms and an "approach" feature which are all optimised automatically. During the first process warm-up the controller familiarises itself with the system dynamics and performs self-optimisation. No user adjustments are required for PID values. Some instruments include an "approach" feature to minimise or eliminate start-up overshoot, also automatically. Setting an appropirate heater output range is an important first part of the tunnig process. If the heater range will not provide enough power, the load will not be able to reach the setpoint temperature. If the range is too high, the load may have very large temperature changes that take along time to settle out. Delicate loads can ever be damaged by too much power. (Dwyer, 2006 – Knospe, 2006).

4.3 Control Outputs

Accurate and reliable energy regulation are essential for good control loop performance if it is assumed that suitable PID values have been determined and applied. Depending on the method of applying energy to the process, for example electrical energy to a resistive heating element, a suitable type of controller output arrangement must be specified. In some cases, more than one output may be required (e.g. for multi-zone heaters, heating-cooling applications). (Dwyer, 2006 – Knospe, 2006).

4.4 Alarms and Safety

Whilst built-in alarms provide a convenient method of “policing” the process against over or under temperature occurrence, they should never be relied upon for plant safety. If there is any possibility that component or sensor failure could result in heating power being permanently applied instead of regulated then a completely independent over-temperature alarm should be utilised. In the event of excessive temperature rise, such an alarm would remove energy from the process. (Dwyer, 2006 – Knospe, 2006).

CHAPTER FIVE
RF COMMUNICATION

5.1 What is RF?

When you hear someone say "RF," he or she is generally referring to radio frequency data communications. In the past, it has also been referred to as RFDC, to differentiate it from radio frequency identification (RFID), which is a different and potentially complementary technology.

RF is the wireless transmission of data by digital radio signals at a particular frequency. It maintains a two-way, online radio connection between a mobile terminal and the host computer. The mobile terminal, which can be portable, even worn by the worker, or mounted on a forklift truck, collects and displays data at the point of activity. The host computer can be a PC, a minicomputer or a much larger mainframe. (Winder & Carr, 2002 – Dawis & Agarwal 2003).

The end result is a seamless flow of information to and from the host, allowing workers to go wherever they need to go to get their job done without fear of being out of touch with the data they need. RFDC improves the timeliness of information, and therefore the value of information, especially in time-sensitive operating environments like cross-dock, make-to-order manufacturing and just-in-time replenishment

Radio Frequency (RF) does not refer just to radio broadcasting but rather encompasses all of the electromagnetic spectrum. RF energy is classified according to frequency. The range of frequencies is Radio Spectrum. While there is no called the precise beginning or end to frequencies making up the RF spectrum, Figure 5.1 shows the generally accepted ranges and class designations. (Winder & Carr, 2002 – Dawis & Agarwal 2003).

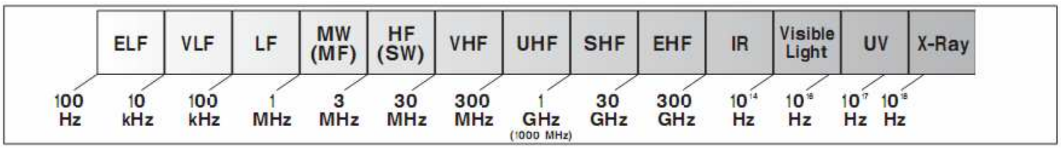


Figure 5.1 Generally accepted ranges and class designations for RF spectrum

5.1.1 System Overview

A basic RF system consists of up to three components:

- A mobile RF terminal;
- A base station (sender/receiver);
- A network controller.

The mobile terminal forms the link (interface) between the user and the RF system. It collects the data to be sent, receives instructions or data from the host, and allows the user to view the data or messages on its display screen. The terminal also has a radio sender/receiver and antenna to provide communication with the rest of the system. (Winder & Carr, 2002 – Dawis & Agarwal 2003).

The base station has a system antenna and acts as a bridge between wireless and wired networks. It is connected to a controller, (controller can be a separate device or included in the base station), which in turn is connected to the host. The“controller” receives and processes information it gets from the host computer and passes this information to the mobile terminals via the base station.

5.1.2 The RF Advantage

The advantages of a RF communication system are many. Start with the simple fact that if it is wireless, you don't have to lay cable all over your facility. Cable is expensive, less flexible than RF coverage and is prone to damage. For new facilities, implementing a wireless infrastructure may be more cost effective than running cable through industrial environments, especially if the space configuration may change to support different storage space allocation or flexible manufacturing stations.

Accessibility is a key benefit. If workers are within range of the system and they always should be if a proper site survey is performed (as explained on page 8) they are always in touch with their data.

Other general advantages of real-time RF communication include a significant improvement in order accuracy (>99%), the elimination of paperwork, replacement of time-consuming batch processing by rapid real-time data processing, prompt response times and improved service levels. (Winder & Carr, 2002 – Dawis & Agarwal 2003).

5.2 Electromagnetic waves

Electromagnetic waves are energy transported through space in the form of periodic disturbances of electric and magnetic fields. All electromagnetic waves travel through space at the same speed, $c = 2{,}99792458 \times 10^8$ m/s, commonly known as the speed of light. An electromagnetic wave is characterized by a frequency and a wavelength. These two quantities are related to the speed of light by the equation,

$$\text{speed of light} = \text{frequency} \times \text{wavelength}$$

5.2.1 Wavelength

Radio waves are composed of both an electrical field and a magnetic field. The wavelength is the length of one wave cycle, which can be measured as the distance between successive wave crests. Wavelength is shown at Figure 5.2.

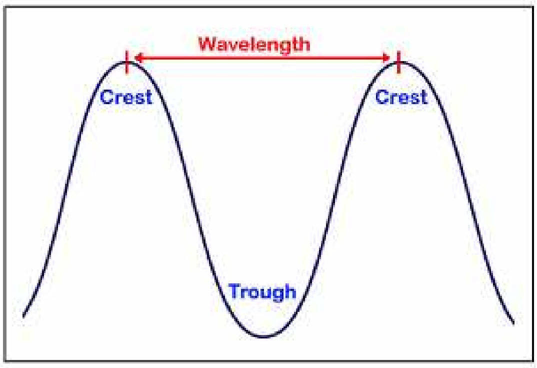


Figure 5.2 Wavelength

5.2.2 Frequency

Frequency refers to the number of cycles of a wave passing a fixed point per unit of time. Frequency is normally measured in Hertz (Hz), equivalent to one cycle per second, andvarious multiples of Hertz. Therefore, the two are inversely related to each other. Shorter wavelengths create higher frequency - the longer the wavelength, the lower the frequency.

The frequency (and hence, the wavelength) of an electromagnetic wave depends on its source. There is a wide range of frequency encountered in our physical world, ranging from the low frequency of the electric waves generated by the power transmission lines to the very high frequency of the gamma rays originating from the atomic nuclei. This wide frequency range of electromagnetic waves constitute the Electromagnetic Spectrum. (Winder & Carr, 2002 – Dawis & Agarwal 2003).

5.2.3 The Electromagnetic Spectrum

The electromagnetic spectrum can be divided into several wavelength (frequency) regions, among which only a narrow band from about 400 to 700 nm is visible to the human eyes. Note that there is no sharp boundary between these regions. The boundaries shown in the above figure are approximate and there are overlaps between two adjacent regions. The eletromagnetic spectrum is shown at Figure 5.3.

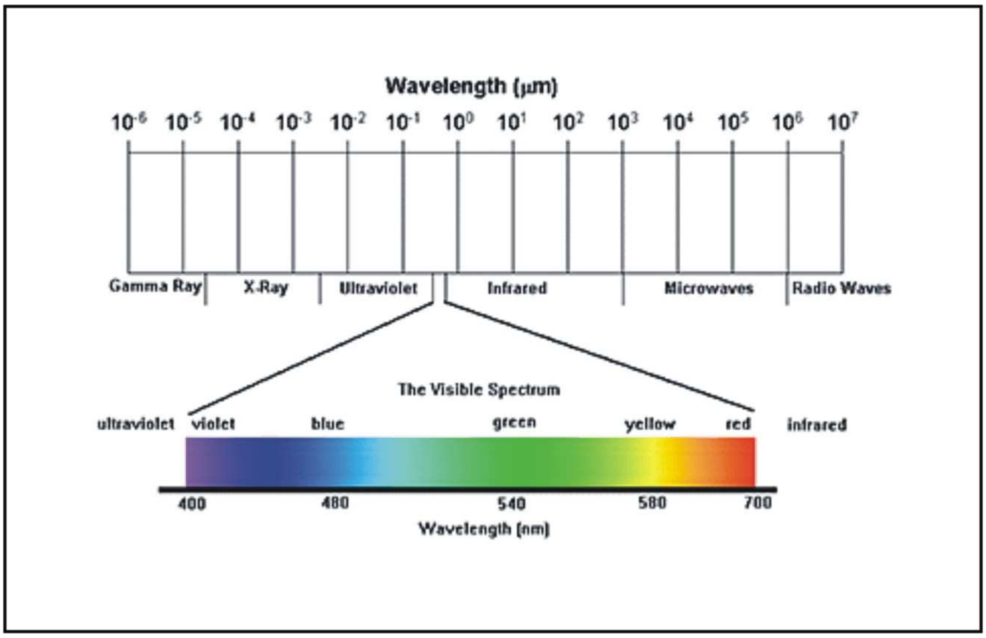


Figure 5.3 Electromagnetic Spectrum

5.2.3.1 Radio waves

Radio waves have the longest wavelength in the electromagnetic spectrum. These waves carry the news, ball games, and music you listen to on the radio. They also carry signals to television sets and cellular phones.

5.2.3.2 Microwaves

Microwaves have shorter wavelengths than radio waves, which heat the food we eat. They are also used for radar images, like the Doppler radar used in weather forecasts.

5.2.3.3 infrared waves

There are infrared waves with long wavelengths and short wavelengths. Infrared waves with long wavelengths are different from infrared waves with short wavelengths. Infrared waves with long wavelengths can be detected as heat. Your radiator or heater gives off these long infrared waves. We call these thermal infrared or far infrared waves. The sun gives off infrared waves with shorter wavelengths. Plants reflect these waves, also known as near infrared waves.

5.2.3.4 Visible light waves

Visible light waves are the only electromagnetic waves we can see. We see these waves as the colors of the rainbow. Each color has a different wavelength. Red has the longest wavelength and violet has the shortestwavelength. These waves combine to make white light.

5.2.3.5 Ultraviolet waves

Ultraviolet waves have wavelengths shorter than visible light waves. These waves are invisible to the human eye, but some insects can see them. Of the sun's light, the ultraviolet waves are responsible for causing our sunburns.

5.2.3.6 X-Rays

X-Rays as wavelengths get smaller, the waves have more energy. X-Rays have smaller wavelengths and therefore more energy than the ultraviolet waves. X-Rays are so powerful that they pass easily through the skin allowing doctors to look at our bones.

5.2.3.7 Gamma Rays

Gamma Rays have the smallest wavelength and the most energy of the waves in the electromagnetic spectrum. These waves are generated by radioactive atoms and in nuclear explosions. Gamma rays can kill living cells, but doctors can use gamma rays to kill diseased cells.

5.3 Antennas

An antenna can be defined as any wire, or conductor, that carries a pulsing or alternating current. Such acurrent will generate an electromagnetic field around the wire and that field will pulse and vary as the electric current does. If another wire is placed nearby, the electromagnetic field lines that cross this wire will induce an electric current that is a copy of the original current, only weaker. If the wire is relatively long, in terms of wavelength, it will radiate much of that field over long distances. (Rudge, 1983 – Johnson, 1993 – Carr, 2001).

The simplest antenna is the "whip". This is a quarter wavelength wire that stands above a groundplane. The most common examples are found on automobiles and are used for broadcast radio, CB and amateur radio, and even for cellular phones. The simplest antenna design is shown at Figure 5.4.

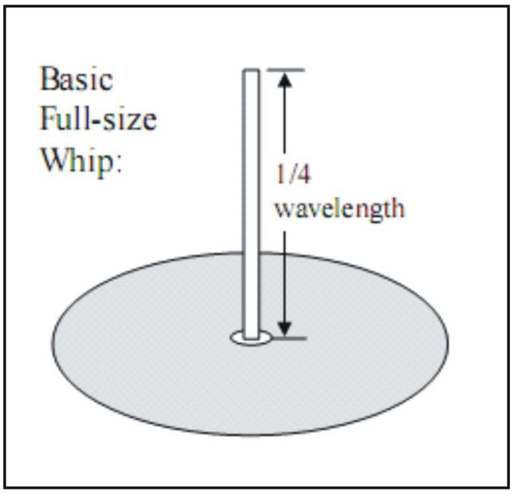


Figure 5.4 The simplest antenna design

All antennas, like any electronic component, have at least two connection points. In the case of the whip, there must be a connection to a ground, even if the groundplane area is nothing more than circuit traces and a battery. The whip and groundplane combine to form a complete circuit. The electromagnetic field is set up between the whip and the ground plane, with current flowing through the field, thus completing the circuit. Ideally, a groundplane should spread out at least a quarter wavelength, or more, around the base of the whip. The groundplane can be made smaller, but it will affect the performance of the whip antenna. The groundplane area must be considered when designing an antenna. (Rudge, 1983 – Johnson, 1993 – Carr, 2001).

The length of the antenna should be measured from the point where it leaves close proximity to ground, or from the transmitter output. If a whip is mounted on a box, and connected to the transmitter with plain wire, that wire becomes part of the antenna! To avoid mistuning the antenna, coaxial cable should be used to connect to an external antenna. On a circuit board, the equivalent to coax is a trace that runs over a groundplane (groundplane on the backside).

5.3.1 Antenna Characteristics

A basic antenna have four main characteristics. These are gain, radiation pattern polarization and impedance.

5.3.1.1 Gain

An antenna that radiates poorly has low “gain”. Antenna gain is a measure of how strongly the antennaradiates compared to a reference antenna, such as a dipole. A dipole is similar to a whip, but the groundplane is replaced with another quarter-wave wire. Overall performance is about the same. An antenna that is 6 dB less than a dipole is -6 dBd. This antenna would offer one half the range, or distance, of the dipole. Compact antennas are often less efficient than a dipole, and therefore, tend to have negative gain. (Rudge, 1983 – Johnson, 1993 – Carr, 2001).

5.3.1.2 Radiation Pattern

Radiation is maximum when broadside, or perpendicular to a wire, so a vertical whip is ideal for communication in any direction except straight up. The radiation “pattern”, perpendicular to the whip, can be described as omnidirectional. There is a "null", or signal minimum, at the end of the whip. With a less than ideal antenna, such as a bent or tilted whip, this null may move and partly disappear. It is important to know the radiation pattern of the antenna, in order to insure that a null is not present in the desired direction of communication.

5.3.1.3 Polarization

It is important that other antennas in the same communication system be oriented in the same way, that is, have the same polarization. A horizontally polarized antenna will not usually communicate very effectively with a vertical whip. In the real environment, metal objects and the ground will cause reflections, and may cause both horizontal and vertical polarized signals to be present. (Rudge, 1983 – Carr, 2001).

5.3.1.4 Impedance

Another important consideration is how well a transmitter can transfer power into an antenna. If the antennatuning circuit on a transmitter (or receiver) is designed for a 50 ohm load, the antenna should, of course, have an impedance near 50 ohms for best results. A whip over a flat groundplane has an impedance near 35 ohms, which is close enough. The impedance changes if the whip is mistuned or bent down, or if a hand or other object is placed close to it. The impedance becomes lower as the antenna is bent closer to ground. When the whip is tilted 45 degrees, the impedance is less than 20 ohms. (Rudge, 1983 – Johnson, 1993 – Carr, 2001).

5.3.2 The Transmitter Antenna

The transmitter antenna allows RF energy to be efficiently radiated from the output stage into free space. In many modular and discrete transmitter designs the transmitter’s output power is purposefully set higher than the legal limit. This allows a designer to utilize an inefficient antenna to achieve size, cost, or cosmetic objectives and stil radiate the maximum allowed output power. Since gain is easily realized at the transmitter, its antenna can generally be less efficient than the antenna used on the receiver. (Winder & Carr, 2002 – Dawis & Agarwal 2003).

5.3.3 The Receiver Antenna

The receiving antenna intercepts the electro-magnetic waves radiated from the transmitting antenna. When these waves impinge upon the receiving antenna, they induce a small voltage in it. This voltage causes a weak current to flow, which contains the same frequency as the original current in the transmitting antenna.

A receiving antenna should capture as much of the intended signal as possible and as little as possible of other off-frequency signals. Its maximum performance should be at the frequency or in the band for which the receiver was designed. The efficiency of the receiver's antenna is critical to maximizing range performance. Unlike the transmitter antenna, where legal operation may mandate a reduction in efficiency, the receiver's antenna should be optimized as much as is practical.

5.4 How Is The Rf Harnessed?

In order for a signal to be transmitted wireless, it is necessary for the signal to be conveyed into free space then recovered and restored to its original form. Two devices are used to accomplish this task: the transmitter and the receiver.

5.4.1 Transmitter

The function of a transmitter is to take an analog or digital signal and, through an antenna, deliver it into free space. A simple transmitter is shown at Figure 5.5

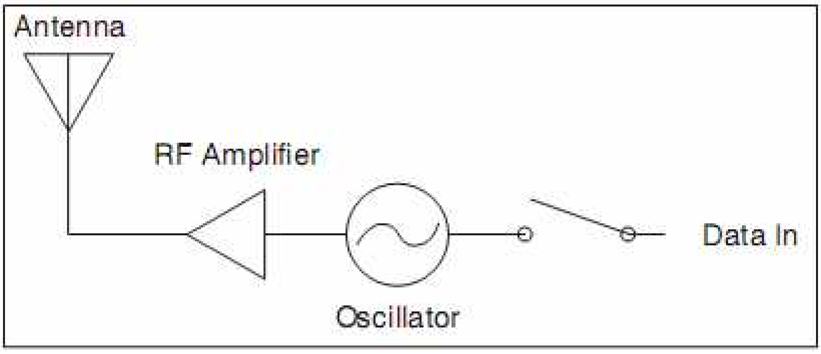


Figure 5.5 Simple Transmitter

You will notice the transmitter has three primary components: a frequency source (the oscillator), a gain stage (the amplifier) and a free space coupler (the antenna). The oscillator generates the frequency at which the transmitter will operate. This frequency is called the Fundamental. In order for the fundamental frequency to be transmitted effectively through the resistance of free space, it is necessary for the signal to be amplified. This is the purpose of the gain stage.

Once the oscillator's frequency has been amplified, it must transition from being a frequency contained within conductors (called transmission lines) into free space. This is the function of the antenna. The transmitting antenna allows the RF energy to be efficiently radiated from the output stage into free space. It is, in essence, a bridge between a guided wave and free space.

5.4.2 Modulation

Now that you have a basic understanding of how a signal finds itself delivered into free space, you may be wondering how any useful information could be represented by that signal. The answer is Modulation. Modulation is the process whereby a carrier medium is impressed with content. The frequency to be controlled is called the Carrier. A carrier is like a moving truck. Just as you might place the contents of your house on the truck, so the information you wish to transmit is loaded onto a carrier. That signal, which has been impressed onto the carrier for "transportation", is called the Program or Control Signal. In the case of digital data transmission, a carrier frequency is modulated with a control signal consisting of binary data. (Winder & Carr, 2002 – Dawis & Agarwal 2003).

While there are many modulation methods, let us consider the simplest and earliest form of modulation, Morse Code. Looking at Figure 5.6 you can see that by turning on and off the carrier to represent the intelligent content of a message, the operator of the telegraph key is serving as the modulation source. Interestingly, this basic form of modulation is still one of the most popular, though today it is known as On-Off Keying (OOK) or Carrier-Present Carrier-Absent (CPCA). By replacing the telegraph key with a microprocessor, a serial transmission link is formed.

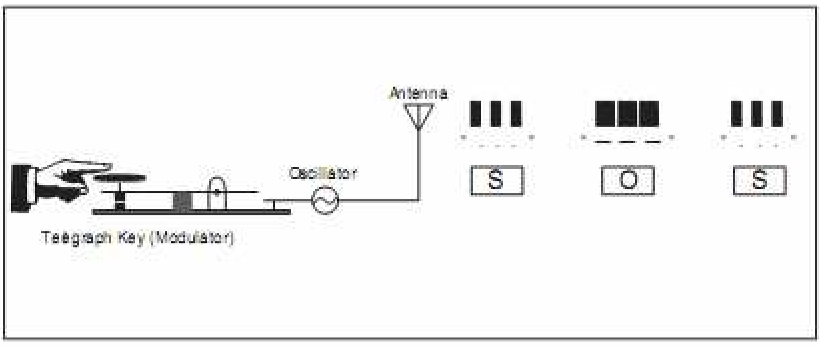


Figure 5.6 Telgraph Key and Carier Signal

5.4.3 Receiver

The purpose of a receiver is to receive the modulated carrier, remove it, and recover the original program signal. This process is called Demodulation.

Figure 5.7 illustrates a single-conversion superhet AM receiver. While receiver topologies vary widely all involve several stages to affect the reception and recovery process. First, the receiving antenna intercepts the electromagnetic waves radiated from the transmitting antenna. When these waves impinge upon the receiving antenna, they induce a small voltage in it. This voltage causes a weak current to flow, which contains the same frequency as the original current in the transmitting antenna. That current is amplified to a more useable level and then fed into a device called a mixer. The mixer takes this incoming signal and combines it with an on-board frequency source called a local oscillator. This converts the signal to a new lower frequency Intermediate Frequency or IF for short. Called the detector then strips out the IF frequency and leaves present only the original information. (Winder & Carr, 2002 – Dawis & Agarwal 2003).

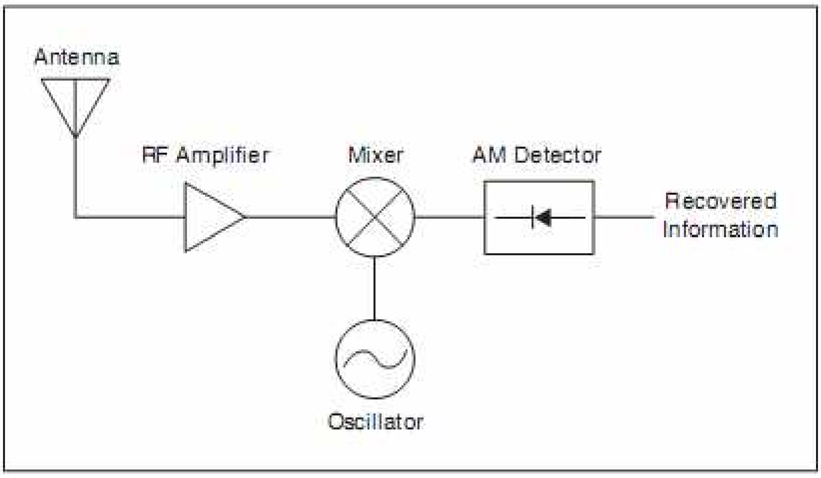


Figure 5.7 Simple Receiver

By now you should have a basic, but clear, understanding of how information signals are transmitted and received. With that as a foundation, you are now ready to consider the steps involved in putting RF to work for you.

5.4.4 Required Bandwidth

The amount of information that can be transferred depends on the carrier frequency and available bandwidth. The carrier frequency must be many times the required bandwidth, thus, applications such as video and data links, which require wide bandwidths, utilize frequencies well into the micro-wave range. In general, the bandwidth should be as narrow as possible to accommodate the required information content. This yields the best immunity to noise and allows the highest possible system sensitivity. (Winder & Carr, 2002 – Dawis & Agarwal 2003).

5.4.5 Power Consumption

In battery-powered applications, power consumption is generally a critical issue. Surprisingly, the relationship between frequency and power consumption is often overlooked. Since propagation efficiency is reduced as frequency climbs, higher frequencies require more power to achieve range. (Winder & Carr, 2002 – Dawis & Agarwal 2003).

CHAPTER SIX
APPLICATION OF TEMPERATURE CONTROL SYSTEM

6.1 Application of Temperature Control

Temperature control systems have electronic power control cards. This cards controls the output power of the systems. While it is controlling the power, it controls temperature. So the control cards are important to control temperatore and power for these systems. The systems must work truely. It must measure true data and gives out true data for optimum controls. Minibar fridges control systems is one of these systems. It controls temperature inside of minibar. Generally, they have one electronic card and it consumes much energy. Simple minibar is shown at Figure 6.1.

Figure 6.1 Simple minibar fridge

Minibars are high-quality, low energy consuming products that have been designed specifically for the hotel market. In basic terms, absorption refrigeration is an established technology in which, compared to a conventional refrigeration system, the compressor is replaced by a complex absorption mechanism that generates the flow of the refrigerant, without any moving mechanical parts. This lack of moving parts guarantees that the operation of the refrigerator is vibration-free and completely silent**,** thereby ensuring a good night sleep for the guest. The investment of an EMS absorption minibar is fully justified by the long maintenance free life-span of the product. The absorption system is shown at Figure 6.2.

Figure 6.2 Absorption system

Minibar fridges uses resistance for cooling system. They have average 65 W resistance. Majority of them works as on-off control system. In this system, when the temperature is high inside of minibar, control card that is in the minibar drives full resistance and gives out full power, so minibar consume maximum energy. When the temperature is low inside of minibar, the control card does not drive resistance. It does not give out power, so minibar does not consume energy. This system has alot of disadvantages. Firstly, it is harmful for resistance. Because it drives resistance full or it does not drive. So resistance's life-span becomes shorter. Secondly, when the inside temperature reaches to set value, resistance is not driven. So systems is off and the temperature begins to increase. The Temperature is never stable for confortable using. Thirdly, its working is realated to outside temperature. If outside temperature is high, inside temperature begins to increase, so it is not stable in summer. Finaly, power consumption is higher in these systems. Because it gives maximum power or does not. Graphic of Power consumption of normal systems and temperature - time graphic are in minibar fridgers is shown at Figure 6.3.

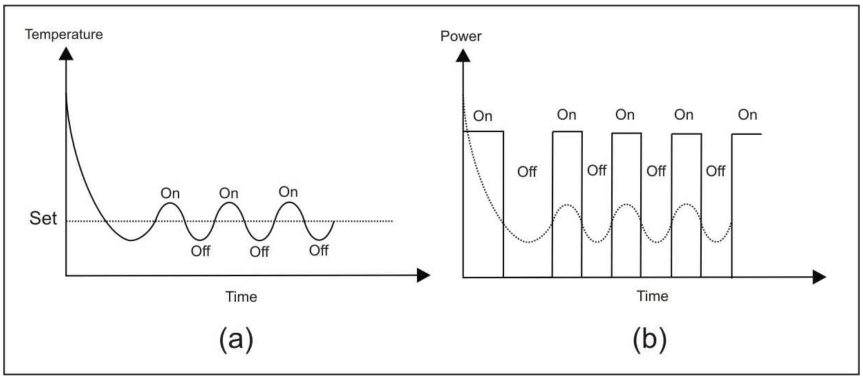


Figure 6.3 (a) temperature – time graphic (b) power consumption – time graphic

The new system that is explained in the thesis has more advantages than normal on-off control systems. It uses fuzzy logic function and makes power saving for minibars. It gives power to resistance and it provides much life –span for resistance. İt gives optimum power to resistance, so temperature is stable for every seasons and power consumption is less tahn normal systems. It has two main cards. These are receiver and transmitter card. Transmitter card is outside and informs receiver card about outside temperature. Receiver card is in the minibar and control resistance power by using fuzzy logic fonction for power saving. Graphic of Power consumption of new systems and temperature - time graphic are in minibar fridgers is shown at Figure 6.4.

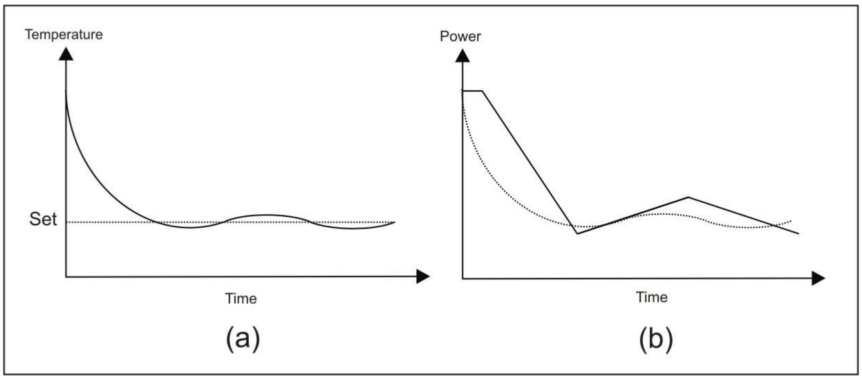


Figure 6.4 (a) temperature – time graphic (b) power consumption – time graphic

6.2 Hardware of Transmitter Main Card

Transmitter main card consists of one display, three buttons that use to arrange temperature set value, one microcontroller and one transmitter module. The schematic of transmitter card is shown at Figure 6.5 .

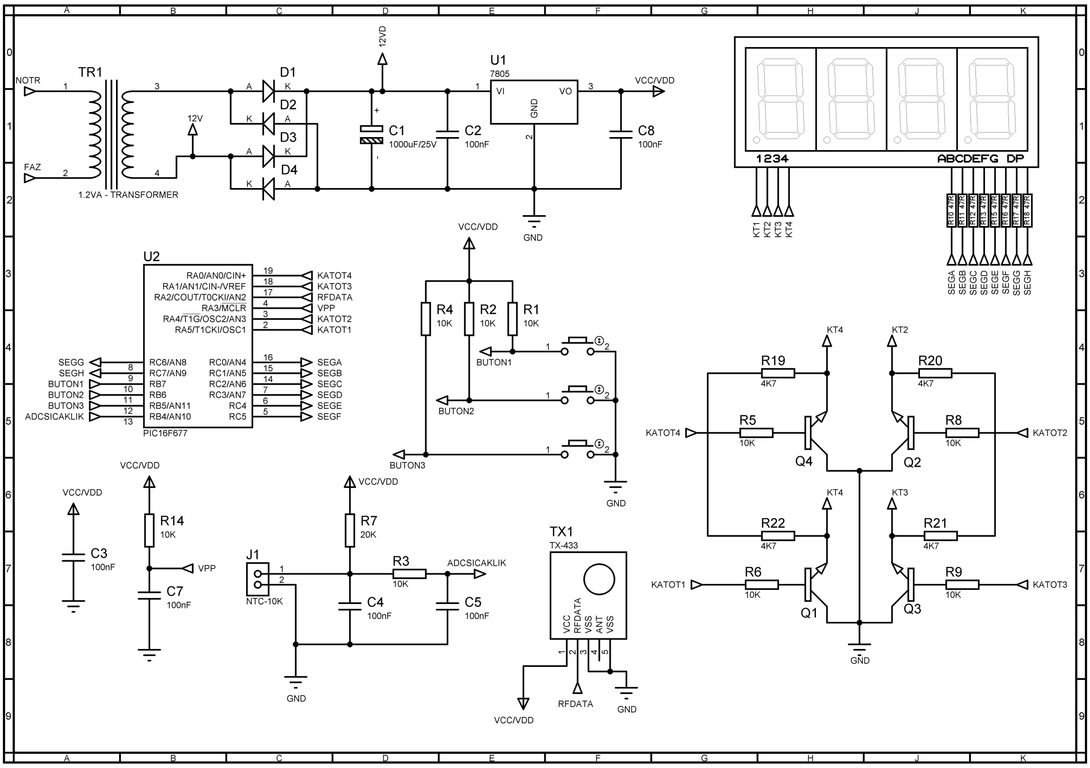


Figure 6.5 The schematic of transmitter card

6.2.1 Explaining Transmitter Process

When the card is powered on, it perceives temperature from outside by negative temperature coeficient of resistance. Microcontroller converts analog value to digital value and shows to user on display. In addition, it sends digital temperature value to receiver card continuously. Firstly data is added to carrying signal that has definite frequency by transmitter module and then the data is sent yo receiver card by transmitter's antenna. The definite frequency is 433Mhz. Transmitter module produces signal at 433Mhz by its resonator. The data that is sent to receiver card consists of transmitter ID code, digital temperature value code, digital temperature value control code and temperature process code. The scheme of transmitter application is shown at Figure 6.6.

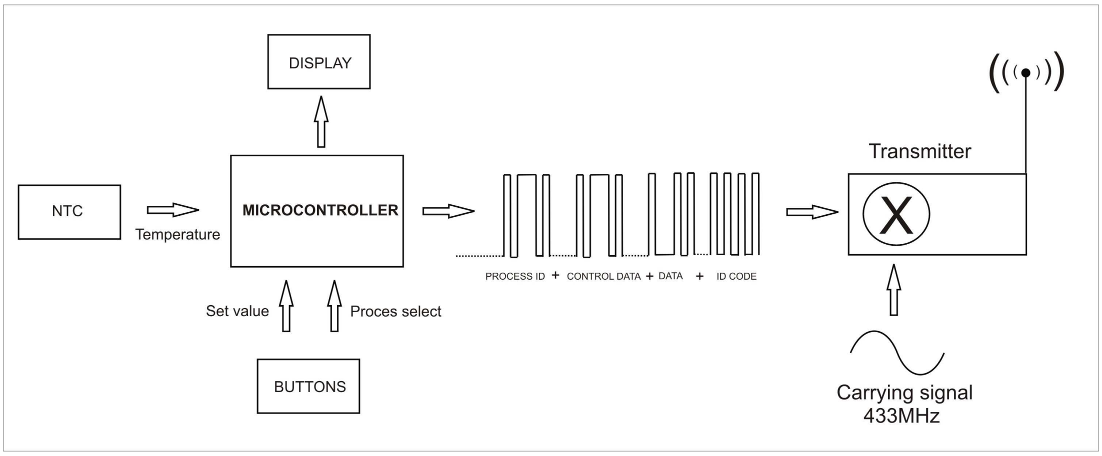


Figure 6.6 The scheme of transmitter application

6.2.2 Algorithm of Transmitter process

When the card is powered on, firstly it runs automatic mode and measures temperature value of outside for fuzzy logic application. Microcontroller shows the temperature value on display. It sends temperature value and informs receiver card about temperature of outside. The temperature value code is processed by microcontroler and temperature value control code is created. It sends temperature control value code to receiver too. So receiver can control the data if is it true. The transmitter card has three buttons. When the user pushes third button, process is changed by microcontroller. It stops measuring and sending outside temperature value. Set value arrangment mode is run. Set value is arranged by buttons. Users enters the set value that they want. Microcontroller shows the set value on display. Set value is increased by first button and decreased by second button. The set value code is processed by microcontroler and set value control code is created. In this mode, The data that is sent to receiver card consists of transmitter ID code, digital set value code, digital set value control code and set process code.

6.3 Hardware of Reciver Main Card

Receiver main card consists of one microcontroller, one display, a power supply curcuit with capasitor, zero cross detection circuit, triac trigerring curcuit and receiver module. . The schematic of receiver card is shown at Figure 6.7.

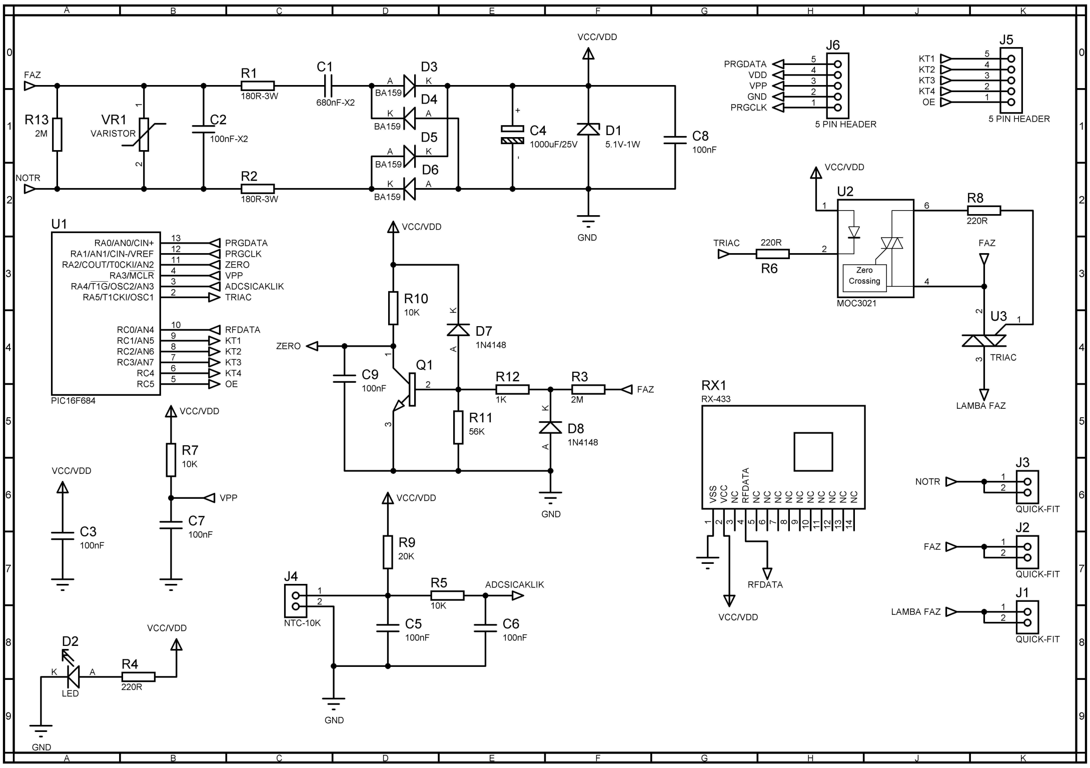


Figure 6.7 The schematic of receiver card

6.3.1 Explaining Receiver Process

When the card is powered on, it waits signal from transmitter. If the signal is not perceived in 5 seconds, microcontroller shows temperature value of inside on display during 5 seconds. After waiting time, it waits the signal again for 5 seconds. When the signal is perceived by receiver module, it is separeted from carrying signal by module. The module uses fitler that has definite frequency for this process. The definite frequency is 433Mhz. After digital value seperated from the signal, it is moved to microcontroller. The scheme of receiver application is shown at Figure 6.8.

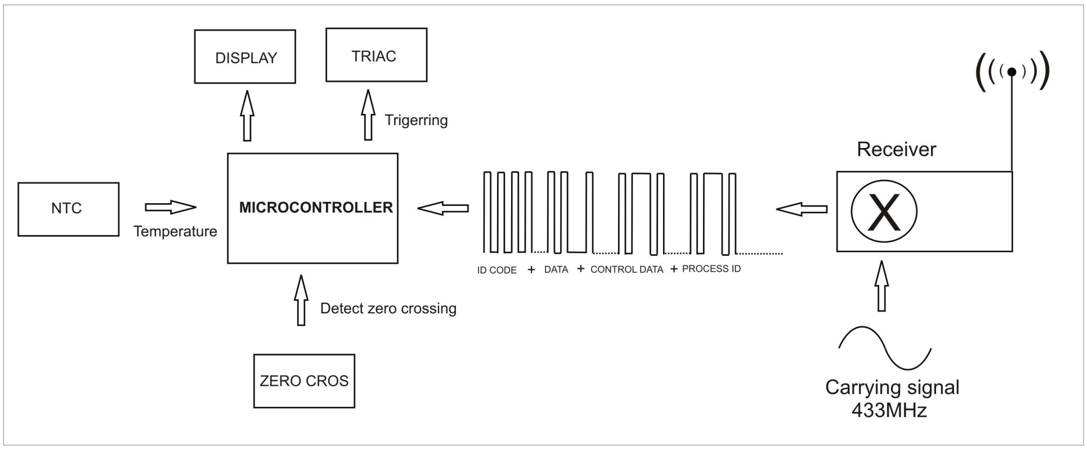


Figure 6.8 The scheme of receiver application

6.3.1.1 Power Supply Curcuit

Power requirements of microcontroller and triac gate are very low, so power can be provided directly from the mains using a low cost power supply circuit. The receiver card power supply curcuit is shown at Figure 6.9.

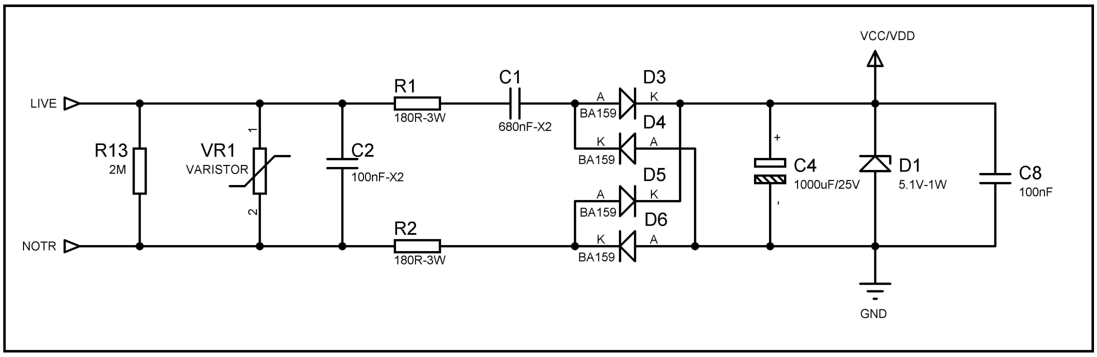


Figure 6.9 The receiver card power supply curcuit

The basic operation of this power supply design is based on bridge diode where the load Capacitor is charged for only whole of the mains cycle. It is therefore necessary to ensure that the circuit can supply enough current to the application without a significant voltage drop, during the mains half cycle where no charging is available.

The available current requirements can be calculated from the following equation:

$$I = \left\{ \frac{230 \quad VAC}{\sqrt{R1^2 + \left(\frac{1}{2\pi \times 50 \times Cdropper} \right)}} \right\}$$

6.3.1.2 Zero Cross Detection Curcuit

It is considerec Voltage Zero Crossing Detection for synchronisation to the Mains. There are many approaches to the detection but in this application example, it is used an external discrete circuit such as the one shown at Figure 6.10.

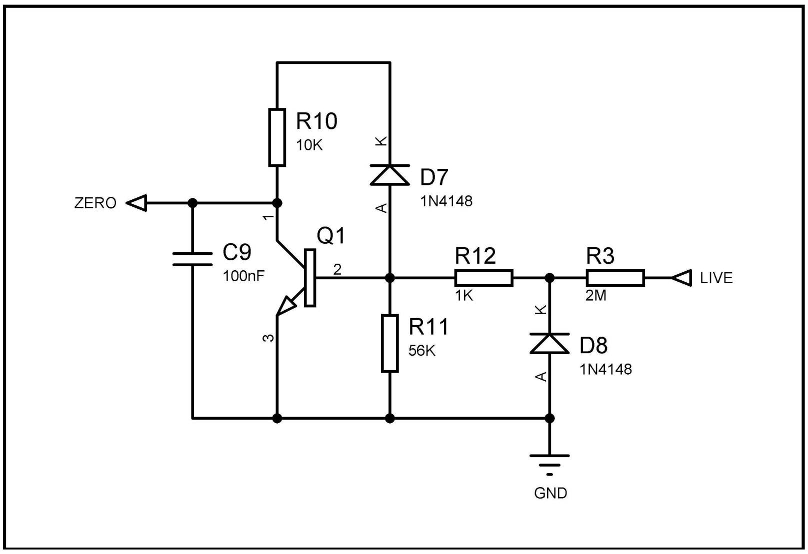


Figure 6.10 The receiver card zero cross detection curcuit

The Zero crossing detector would normally be used to generate an external Interrupt to the Microcontroller, providing synchronisation to the mains supply. Using both Positive and Negative crossing points has one limitation in that the resulting detection produces unequal timing reference points. Typically the first half cycle is approximately 8.5 mS and the second is approximately 11.5 mS for a 50 Hz supply. The reason for this is that a standard CMOS input pin is used for the zero crossing detection, the Low to High and High to Low threshold voltages are not equal and thus switch at different times. This can be compensated for in the software to avoid triggering the Triac at the wrong point in the second half cycle.

6.3.1.3 Triac Trigering Curcuit

It is used an optocoupler for trigering curcuit. Optocoupler seperates analog signals and digital signals on the card for electro magnetic conformity. The receiver card triac trigering curcuit is shown at Figure 6.11.

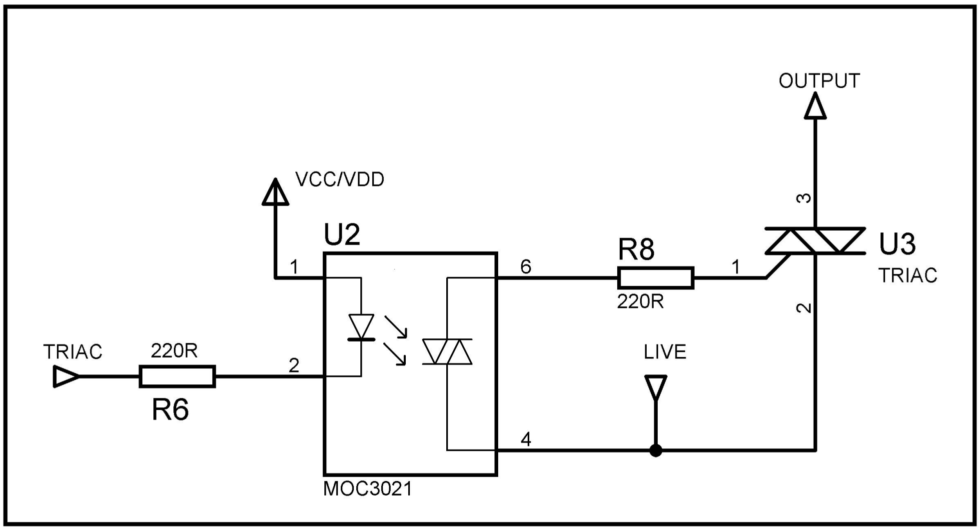


Figure 6.11 The receiver triac trigering curcuit

In this application, MOC3021 is used as optocoupler. Ther is not zero cross detection unit in the optocoupler, so triac is trigered randomly. This curcuit is suitable for dimmer aplications. If the card is control motor, there must be zero cross detection unit in the optocoupler. In this curcuit, microcontroler trigers led that is in optocoupler and led trigers optotriac that is in optocoupler. This triac connects lıve line to gate of the triac that is on the main card and drives the triac.

6.3.2 Algorithm of Receiver Process

The microcontroller takes first 8 bit that is transmitter ID of the digital data and compares self receiver ID. If they are not same, microcontroller breaks the process and waits new data from transmitter. If they are same, The microcontroller takes fourth 8 bit that is process ID of the digital data and compares self process IDs. If process ID is same temperature process ID, it goes to automode process, If process ID is same set process ID, it goes to manuel mode process.

In automode process, The microcontroller takes second and third 8 bit that is temperature value code and temperature value control code of the digital data. The temperature value code is processed by microcontroler and temperature value control code is created. Then, two conrols codes that one is received from transmitter and one is created by microcontroller are compared. If they are not same, the microcontroller breaks the process and waits new data from transmitter. If they are same, it goes to fuzzy logic process.

In fuzzy logic process, microcontroller arranges control data to control triac, so it controls power copnsumption. Microcontroller has three data. They are temperature that is received from transmitter, temperature that is measured inside and database that consists of fuzzy value as fuzzy table. The microcontroller calculates an optimum value for control process by using these three data. It uses temperature values and finds the control value from fuzzy table. Fuzzy table and control values are shown at Table 6.1.

Table 6.1 Fuzzy table and control values

	Outside	**Very cold**		**Cold**		**Normal**		**Hot**		**Very hot**	
Inside	C º	0 - 5	5 - 10	10 - 15	15 - 20	20 - 25	25 - 30	30 - 35	35 - 40	40 - 45	50 - 55
Cold	-20-10	-6	-5	-4	-3	-2	-1	0	1	2	3
	-10 -0	-5	-4	-3	-2	-1	0	1	2	3	4
Nor.	0 - 10	-4	-3	-2	-1	0	1	2	3	4	5
	10 -20	-3	-2	-1	0	1	2	3	4	5	6
Hot	20-30	-2	-1	0	1	2	3	4	5	6	7
	30-40	-1	0	1	2	3	4	5	6	7	8

The microcontroller uses the control value which is taken from the table for driving triac. For example, it takes 5 value from table. While it is diriving triac, it added 10 to 5. it drives triac after 20 -15 = 5 msn. So, triac does not drive full and power consumption is less than full driving. Fuzzy table is prepared for optimum control value in every condution. The control values and power consumption that is in fuzzy porcess is shown at Table 6.2.

Table 6.2 Power consumption in fuzzy logic porcess

Control values	Volt (VAC)	Amper (A)	Power (w)	Energy (kW/h)
-6	85	0.10	8	0,19
-5	100	0.10	10	0,24
-4	120	0.11	13	0,31
-3	130	0.14	18	0,43
-2	140	0.14	21	0,50
-1	145	0.15	22	0,52
0	155	0.19	30	0,72
1	175	0.19	33	0,79
2	185	0.20	37	0,88
3	195	0.20	39	0,93
4	200	0.21	42	1,00
5	205	0.22	45	1,08
6	210	0.24	50	1,20
7	215	0.24	52	1,32
8	220	0.25	55	1,32

When the outside temperature is low and inside temperature is low, control output that arranges power consumption is lower value. But if outside temperature is high, control output is higher value than normal. Microcontroller controls output value and power consumption by looking fuzzy table. The triac driving during power saving in fuzzy process is shown at Figure 6.12.

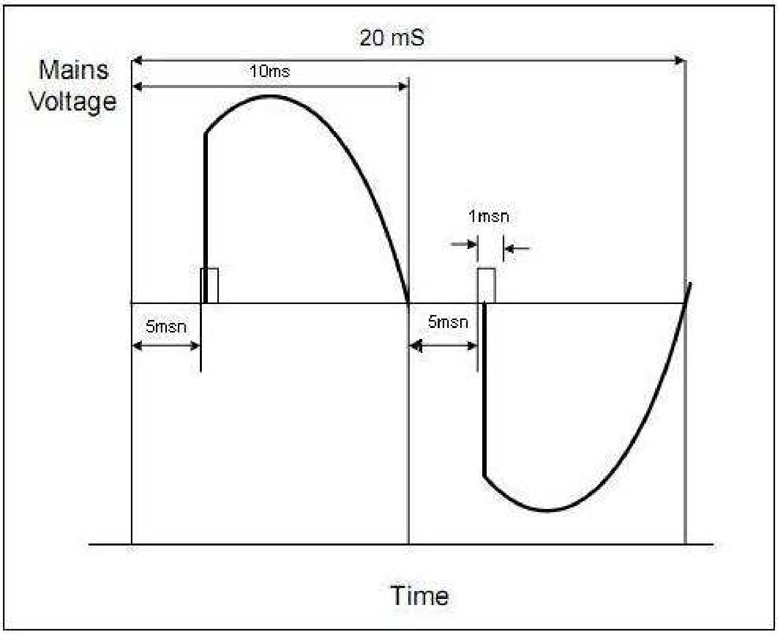


Figure 6.12 The triac driving during power saving in fuzzy process

In manuel mode process, The microcontroller takes second and third 8 bit that is set value code and set value control code of the digital data. The set value code is processed by microcontroler and set value control code is created. Then, two conrols codes that one is received from transmitter and one is created by microcontroller are compared. If they are not same, the microcontroller breaks the process and waits new data from transmitter. If they are same, it goes to proportional control process. The control values and power consumption that is in fuzzy porcess is shown at Table 6.3.

In proportional control process, microcontroller arranges control data to control triac, so it controls power copnsumption. Microcontroller has two data. They are set value that is received from transmitter and temperature that is measured inside. Set value is subtracted from temperature value by microcontroller and so it measures aproach of temperature value to set value. If result of subtraction is bigger than 10, microcontroller drives triac full, but the result of subtraction is smaller than 10, it drives triac as proportional. The control values that is in manuel mode process is shown at Table 6.3. So power consumption is not %100 and it decreases as proportional too.

Table 6.3 Control values in manuel mode porcess

	Outside	Very cold		Cold		Normal		Hot		Very hot	
Inside	C º	0 - 5	5 - 10	10 - 15	15 - 20	20 - 25	25 - 30	30 - 35	35 - 40	40 - 45	50 - 55
Cold	-20-10	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5
	-10 -0	(-5)-5	(-5)-5	(-5)-5	(-5)-5	(-5)-5	(-5)-5	10	10	10	10
Nor.	0 - 10	(-5)-5	(-5)-5	(-5)-5	(-5)-5	(-5)-5	(-5)-5	10	10	10	10
	10 -20	10	10	10	10	10	10	10	10	10	10
Hot	20-30	10	10	10	10	10	10	10	10	10	10
	30-40	10	10	10	10	10	10	10	10	10	10

When we compare fuzzy and manuel mode processes, we can show fuzzy proceses have more advantage and more power saving than manuel mode process. Because in manual mode, system is not dependent to outside temperature, so it does not estimate to become cold inside temperature in the course of time and give more power to resistance. But in fuzzy process, it knows to become cold inside temperature according to outside temperature, and gives output less power than manuel mode process. Table 6.4 and 6.5 show power consumption in two processes. In fuzzy process, system consume 27,6W power on an average, in manuel mode processes, power consumption is 40W power on an average. These vaules is found by arithmetic average.

Table 6.4 Power consumption in fuzzy porcess

	Outside	Very cold		Cold		Normal		Hot		Very hot	
Inside	C º	0 - 5	5 - 10	10 - 15	15 - 20	20 - 25	25 - 30	30 - 35	35 - 40	40 - 45	50 - 55
Cold	-20-10	8w	10w	13w	18w	21w	22w	30w	33w	37w	39w
	-10 -0	10w	13w	18w	21w	22w	30w	33w	37w	39w	42w
Nor.	0 - 10	13w	18w	21w	22w	30w	33w	37w	39w	42w	45w
	10 -20	18w	21w	22w	30w	33w	37w	39w	42w	45w	50w
Hot	20-30	21w	22w	30w	33w	37w	39w	42w	45w	50w	52w
	30-40	22w	30w	33w	37w	39w	42w	45w	50w	52w	55w

Table 6.5 Power consumption in manuel porcess

	Outside	**Very cold**		**Cold**		**Normal**		**Hot**		**Very hot**	
Inside	C º	0 - 5	5 - 10	10 - 15	15 - 20	20 - 25	25 - 30	30 - 35	35 - 40	40 - 45	50 - 55
Cold	-20-10	10w	10w	10w	10w	10w	10w	10w	10w	10w	10w
	-10 -0	10w-30w	10w-30w	10w-30w	10w-30w	10w-30w	10w-30w	10w-30w	10w-30w	10w-30w	10w-30w
Nor.	0 - 10	30w-60w	30w-60w	30w-60w	30w-60w	30w-60w	30w-60w	30w-60w	30w-60w	30w-60w	30w-60w
	10 -20	60w	60w	60w	60w	60w	60w	60w	60w	60w	60w
Hot	20-30	60w	60w	60w	60w	60w	60w	60w	60w	60w	60w
	30-40	60w	60w	60w	60w	60w	60w	60w	60w	60w	60w

CHAPTER SEVEN
CONCLUSION

The most important part of power control curcuits is output control unit. If it gives out less energy, load takes less energy from line. So ıf you control the output unit, you can control your product to consume less energy. In this thesis, power control curcuit that control output by using its hardware and software and the methods that it uses for the less power consumption like fuzzy logic, rf communication and proportional control function are explained. In addtion, this curcuit is applied to minibar cooling system and the results of the normal system and this system are compared. Power saving in the system that uses fuzzy logic and rf is proofed. Measurements and results are shown in chapter six with tables and graphics. The system consist of two cards. The receiver card takes information about outside temperature of minbar from the transmitter card, it measures tempereature inside of minibar and it provides power saving at working. it uses fuzzy logic to give optimum output. The transmitter card uses rf communication to inform about outside temperature of minibar.

The system that is explained in the thesis is developed much. The transmitter card's display is changed to LCD. The more buttons can be added and the more data is loaded by users. These data can be timer or clock functions. The more sensors can be added to measure temperature from different points outside. So average of outside temperature can be found to give more stable information to receiver card. The more data is sent to receiver card like timer and clock function. In the receiver card, fuzyy table is changed or extended, so power saving is more sensitive. The power supply curcuit is consicuited with transformer for security. The rf communication can be make double direction. So transmitter card is informed about inside of minibar and it informs to user about inside temperature of minibar. All of them provides more confortable for consumer.

REFERENCES

Anderson, N. A. (1998). Instrumantation for process measurement and control, London : CRC Press

Antennas: Design, Application, and Performance. (n.d) Retrieved september 14, 2007, from http://www.linxtechnologies.com/Support/Application-Notes/

Automatic control forms. (n.d) Retrieved August 21, 2007, from http://www.elimko.com.tr/v1.5/condocs//prods/otomatikformlar

Basic control loop. (n.d). Retrieved August 25, 2007, from http://www.dmccormick.org/Control%20Technology/BasicLoop.pdf

Bojadziev, G. (1996). Fuzzy sets, Fuzzy logic, Applications London : Imperial college press

Bradley, D.A. (1995). Power electronics. London : Chapman & hall

Carr, J. J. (2001). Practical Antenna Handbook, Australia: McGraw-Hill

Childs, P. R. N. (2001). Practical Temperature Measurement. Oxford: Elsevier

Davis, W. A., & Agarwal, K. (2003). Radio Frequency Circuit Design, Newyork: Wiley press

Dwyer, A. (2006). Handbook of Pi And Pid Controller Tuning Rules, London: Imperrial College pres.

Fox, J. (1981). Towards a reconicilation of fuzzy logic and standart logic, *Journal of Man-Mach, 15,* 213-220.

Haack S. (1981). Do we need fuzzy logic, *Journal of Man-Mach,11 ,* 437-445.

Harriot, P. (1964). Process Control, Australia: McGraw-Hill

Johnson, R. G. (1993). Antenna Engineering Handbook, Australia: McGraw-Hill

Klir, G. J., & Yuan B. (Eds). (1996). Fuzzy sets, Fuzzy logic and fuzzy systems, London : Imperial college press

Knospe, C. (2006). PID Control, *IEEE* Control Systems Magazine 26, 30-31.

Korner, S. (1967). Laws of thought. Encyclopedia of philosophy, (4th ed.). (414-417). NY : MacMillian

Kruse, R., & Gebhardt, J., & Klawon, F. (1994). Foundations of Fuzzy systems. Chichester: Wiley

Lejewski, C. (1967). Jan Lukasiewicz. Encyclopedia of philosophy, (5th ed.). (104-107). NY: MacMillian

Maloney, T.J. (1986). Industrial electronics. New Jersey: Prentice-Hall

Mandini, E.H., & Gaines, B.R. (1981). Fuzzy reasoning and its applications, London : Academic press.

Marston, R. M. (1999). Optoelectronics circuits manual, Oxford: Elsevier

Marston, R. M. (1997). Power control circuits, Oxford: Elsevier

McMillian, G. K., & Considine, D. M. (1999). Process/Industrial Instruments and Controls HandBook, Australia: McGraw-Hill.

Patrick, D. R., & Fardo, S. W. (1997). Industrial Process Control Systems, Canada : Delmarlearning.

PID Temperature Control. (n.d). Retrieved August 8, 2007, from www.lakeshore.com/pdf_files/Appendices/LSTC_appendixF_l

PID Tips. (n.d). Retrieved August 31, 2007, from http://www.unitronics.com/Data/Uploads/Miscellaneous/PID_Tips_1.pdf

Rf wireless basics. (n.d). Retrieved september 5, 2007, from http://www.lxe.com/us/tutorials/whitepapers.aspx

Rf 101 information for the rf challenged. (n.d). Retrieved september 10, 2007, from http://www.linxtechnologies.com/Support/Application-Notes/

Ross, T. J. (2004). Fuzzy logic with engineering applications, Newyork: Wiley press

Rudge, A. W. (1983). The Handbook of Antenna Design, London : IET

Temperature controllers. (n.d). Retrieved August 28, 2007, from http://www.rhomberg.com.au/downloads/Thermoline%20Introduction.pdf

Types of Feedback Control. (n.d). Retrieved August 13, 2007, from http://newton.ex.ac.uk/teaching/

Webb, C. R. (1964). Automatic Control, Australia: McGraw-Hill

Williams, B.W. (1987). Power electronics : Devices, Drivers and Applications, New York : Wiley

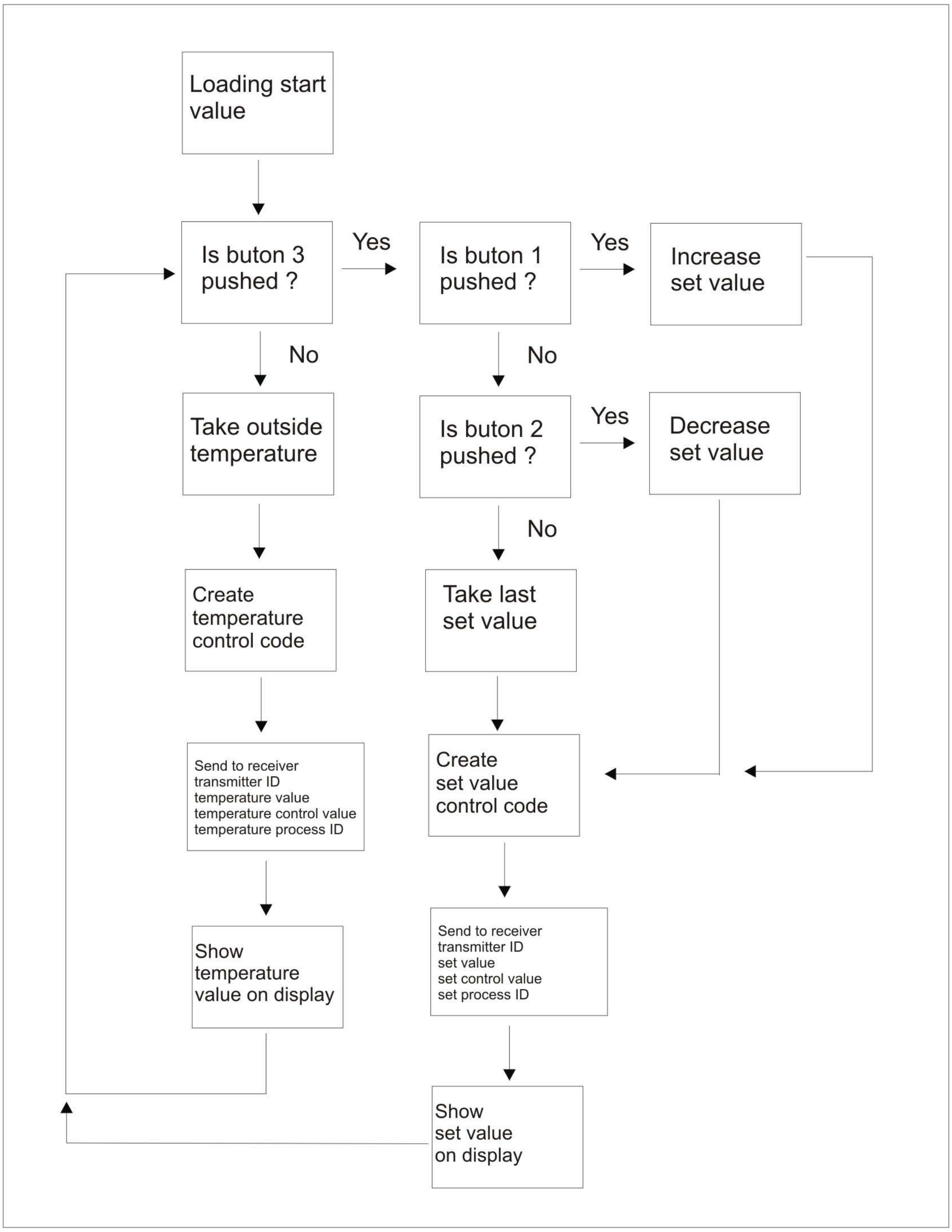
Winder, S., & Carr J. J. (2002). Radio and RF engineering Pocket book, Oxford: Elsevier

Zadeh, L. A. (1965). Fuzzy sets, information control, 8, 338-353

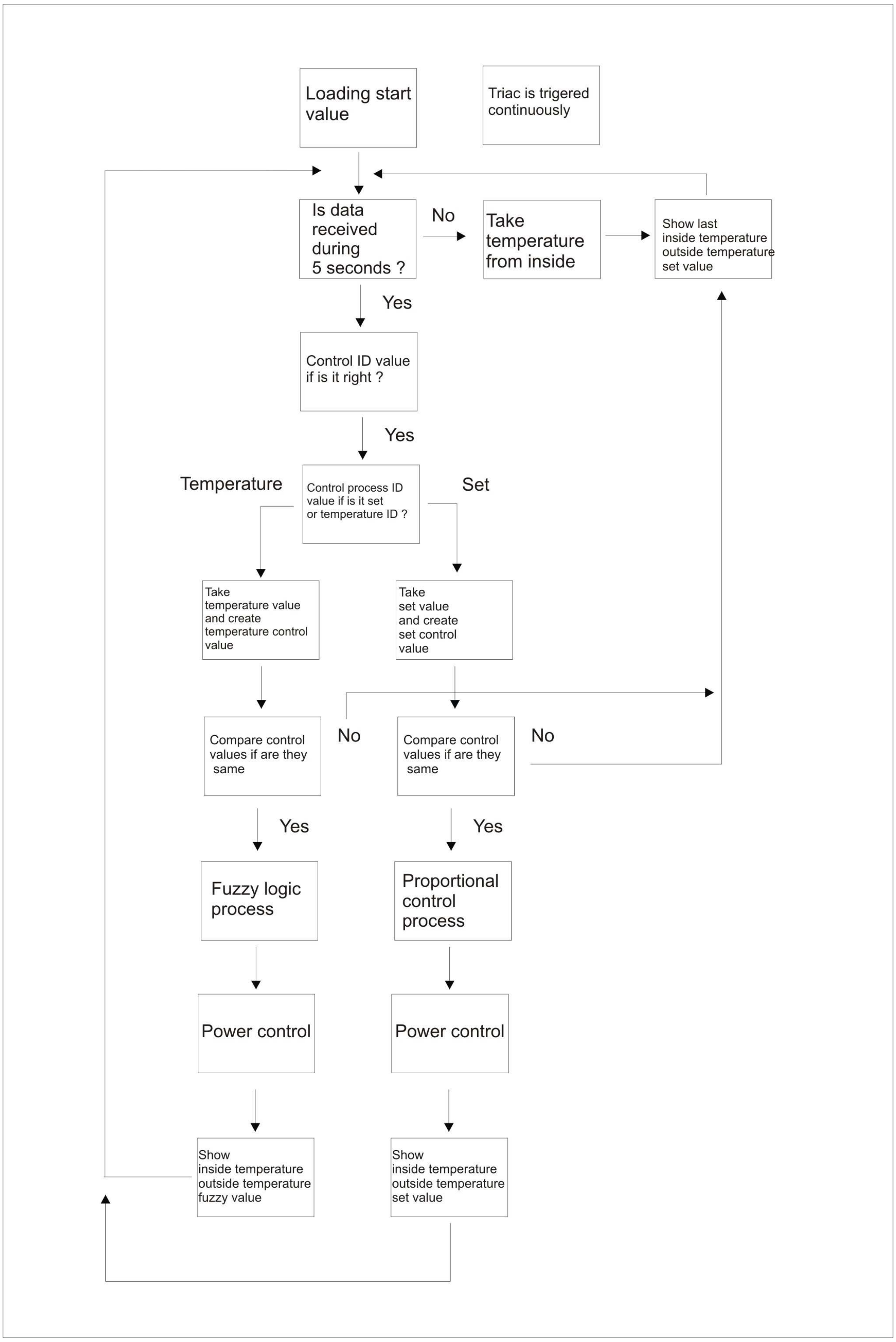
Zadeh, L. A. (1984). Making computers think like people, *IEEE Spectrum* 8, 26-32.

Zimmermann, H.J. (1987). Fuzzy sets, Decisionmaking and expert systems. Boston : Kluwer

APPENDIX A : ALGORITHM OF TRANSMITTER AND RECEIVER APPLICATION



The algorithm of transmitter application

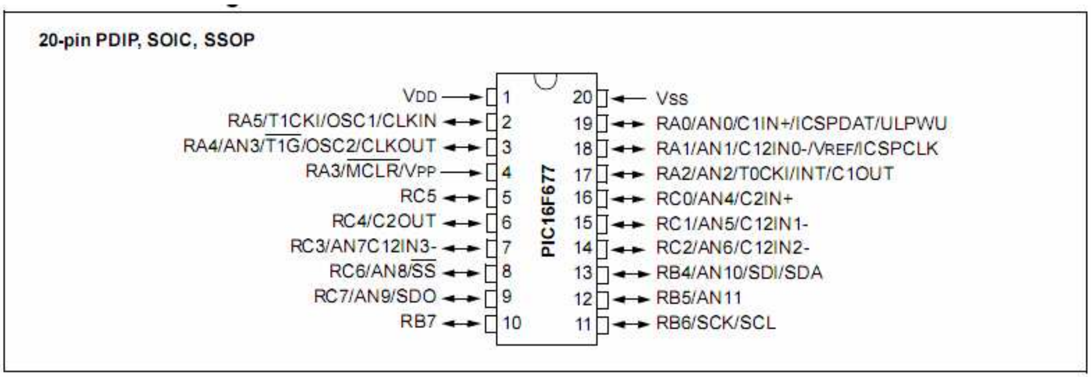


The algorithm of receiver application

APPENDIX B : MICROCONTROLLER FEATURES OF TRANSMITTER AND RECEIVER MAIN CARD

PIC16F677:

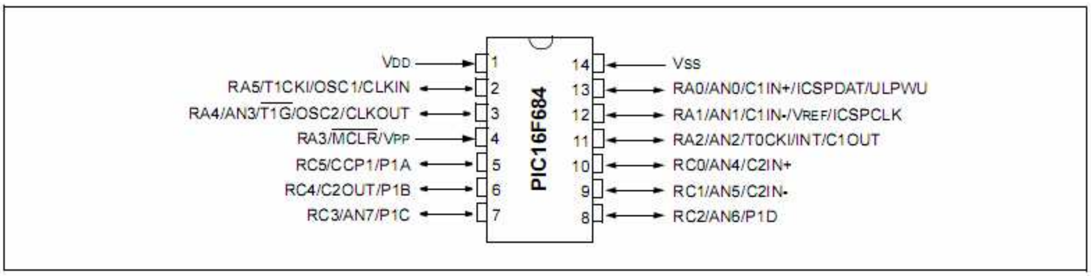
- High-Performance RISC CPU
- Only 35 instructions to learn
- Operating speed:
- Interrupt capability
- 8-level deep hardware stack
- Direct, Indirect and Relative Addressing modes
- Precision Internal Oscillator
- Power-Saving Sleep mode
- Wide operating voltage range (2.0V-5.5V)
- Industrial and Extended Temperature range
- Power-on Reset (POR)
- Power-up Timer (PWRTE) and Oscillator Start-up
- Brown-out Reset (BOR) with software control
- Enhanced low-current Watchdog Timer (WDT)
- Multiplexed Master Clear/Input pin
- Programmable code protection
- High Endurance Flash/EEPROM cell:
- Enhanced USART module:



The pin diagram of 16F677

PIC16F684:

- High-Performance RISC CPU
- Only 35 instructions to learn
- Operating speed:
- Interrupt capability
- 8-level deep hardware stack
- Direct, Indirect and Relative Addressing modes
- Precision Internal Oscillator:
- Software Selectable 31kHz Internal Oscillator
- Power-Saving Sleep mode
- Wide operating voltage range (2.0V-5.5V)
- Industrial and Extended Temperature range
- Power-on Reset (POR)
- Power-up Timer (PWRT) and Oscillator Start-up
- Brown-out Reset (BOR) with software control
- Enhanced low-current Watchdog Timer (WDT)
- Multiplexed Master Clear with pull-up/input pin
- Programmable code protection
- High Endurance Flash/EEPROM cell



The pin diagram of 16F684